STATUS OF CERES CLOUD PRODUCTS

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May 2-3, 2006

CERES Cloud Products

- Validation & Assessment Continues
  - -calibration
  - - surface comparisons
  - - other instrument comparisons

- Edition 3 will start later this year
  - - improved mask
  - - new products
  - - expect beta runs in July 2006

CALIBRATION MONITORING

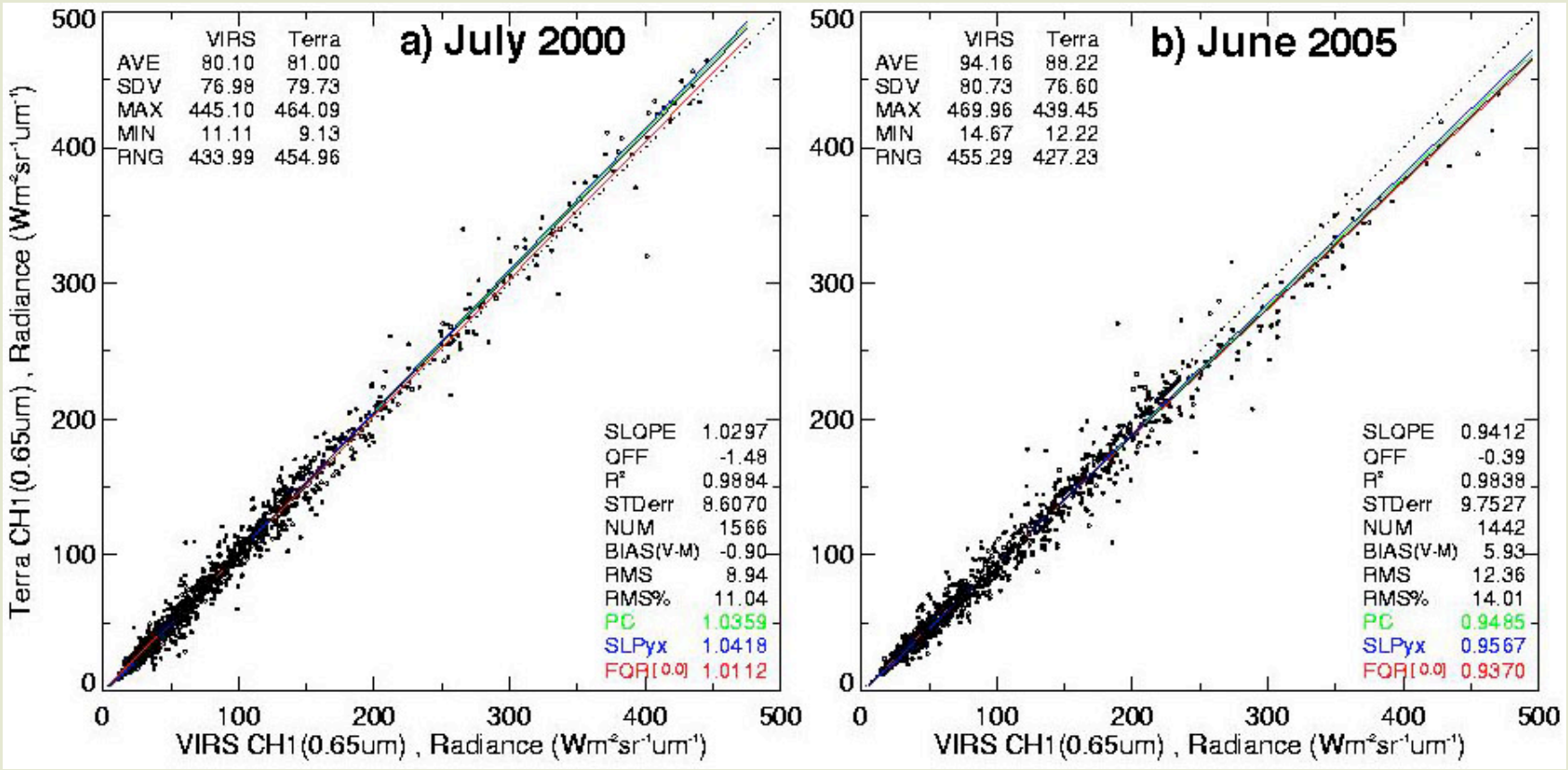
- Aqua vs Terra (match in polar regions only) vs VIRS
- MODIS vs CERES

EXAMINE RELATIVE TRENDS IN IMAGER CHANNELS

Terra-VIRS, VISIBLE

Compute slope for each month

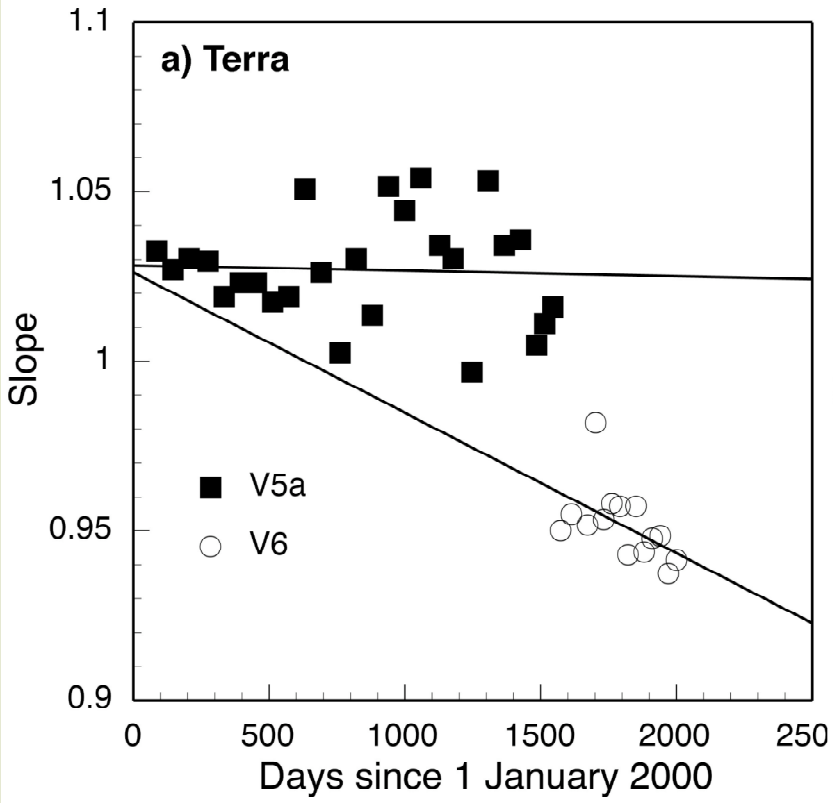
VIRS Version 5a **Version 6**



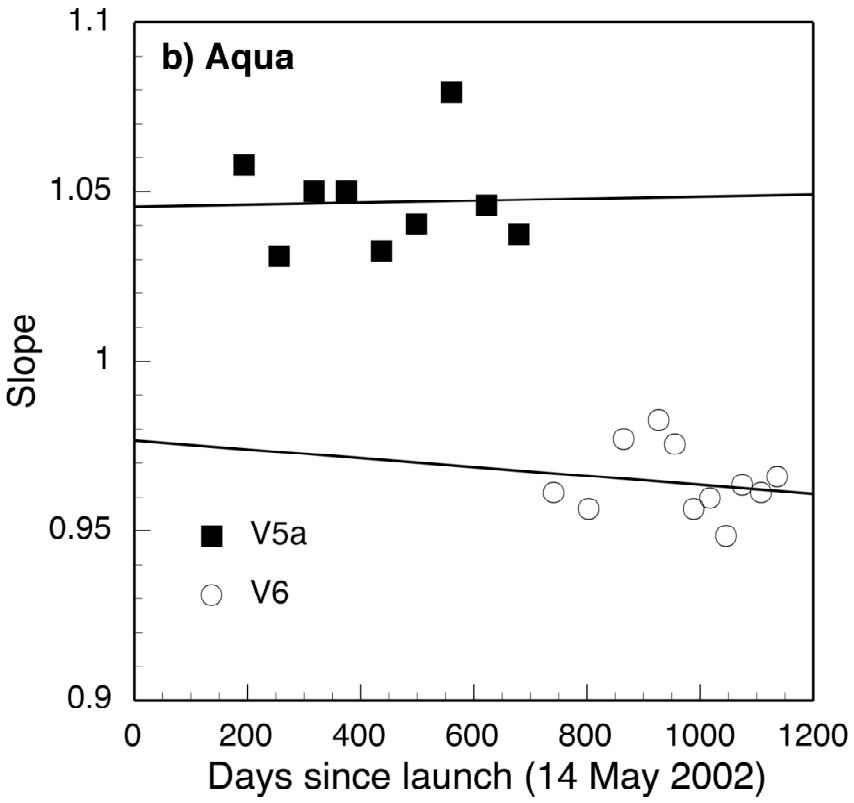
EXAMINE RELATIVE TRENDS IN IMAGER CHANNELS

VISIBLE

VIRS vs Terra



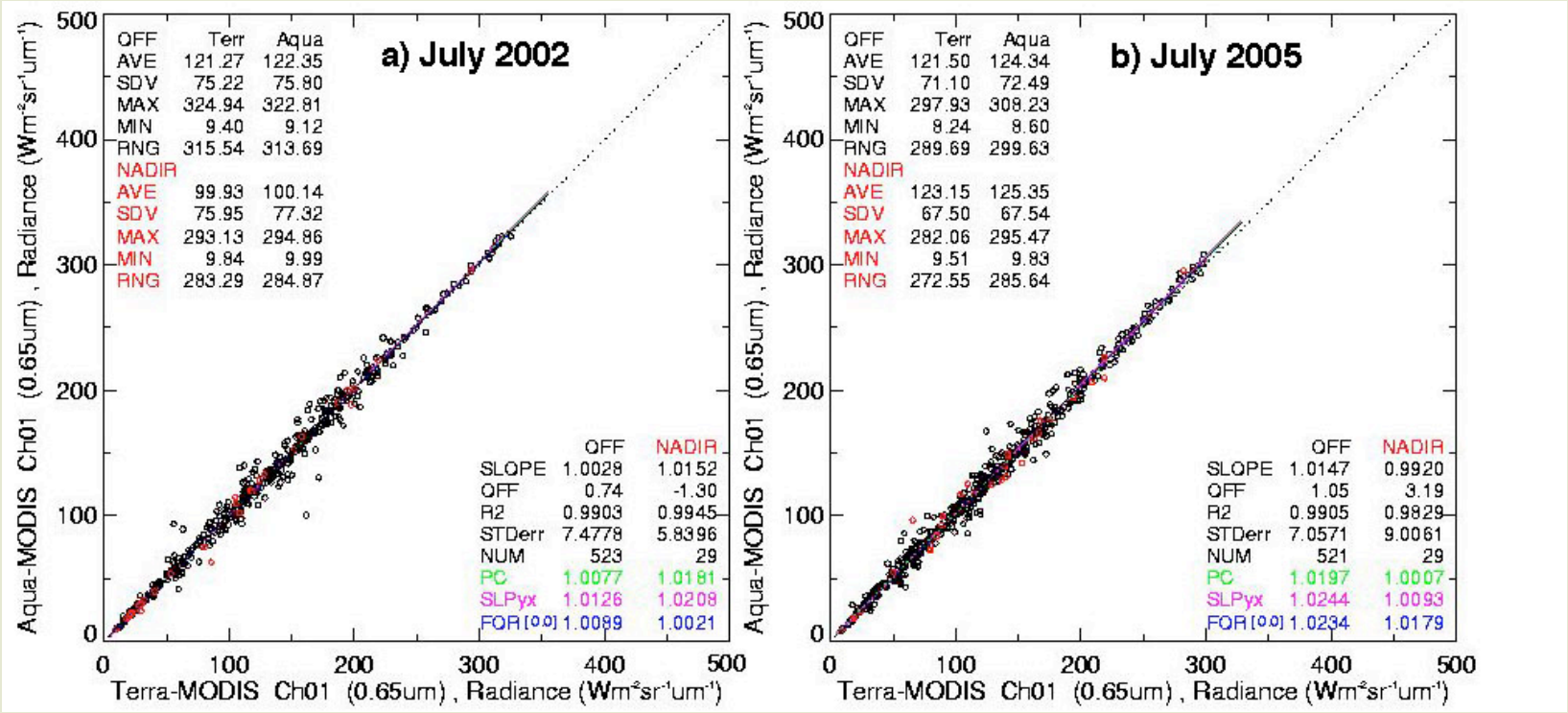
VIRS vs Aqua



- Aqua brighter (1-2%) than Terra
- VIRS V5a appears to be ok, V6 seems to have added a trend!

MORE VISIBLE CHANNEL COMPARISONS

Terra vs Aqua

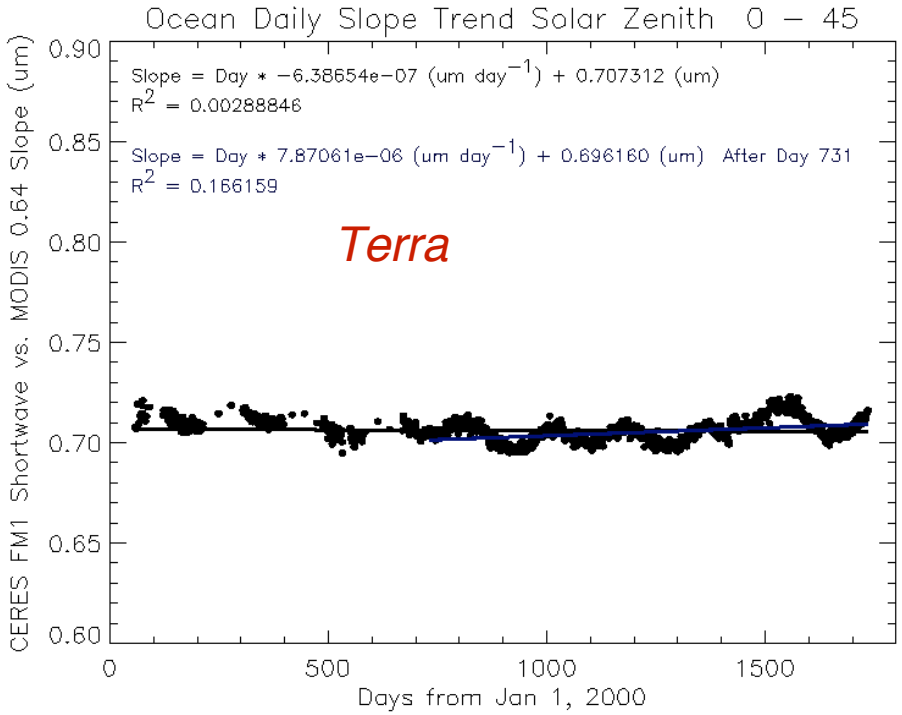


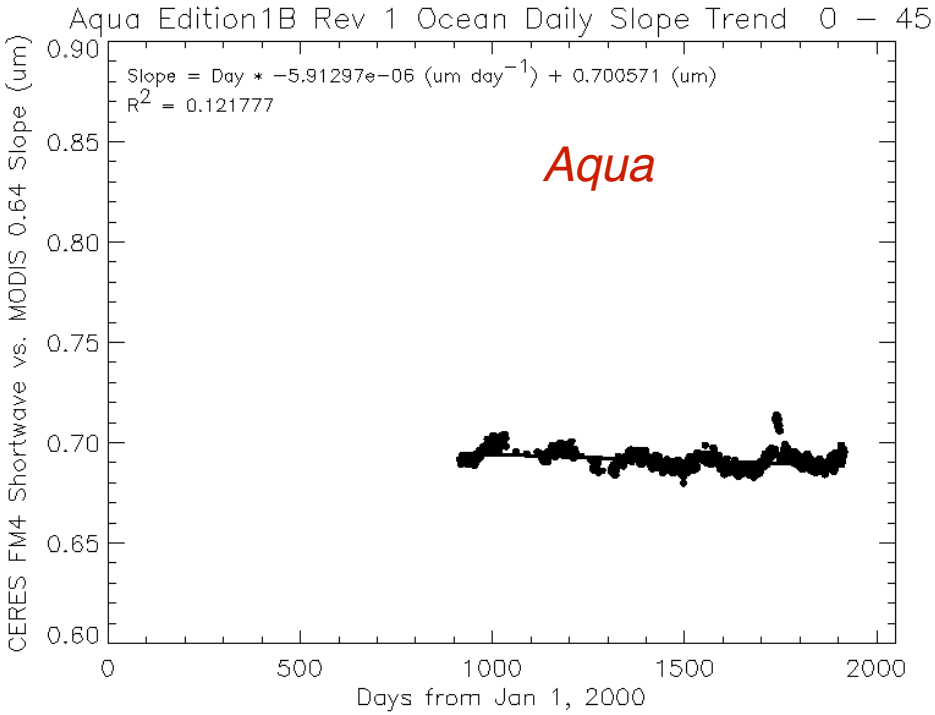
- Aqua brighter (1-2%) than Terra in direct comparison
- Confirms VIRS V5a conclusion

INTERCALIBRATIONS

Comparison of CERES SW and MODIS 0.635 μm, Jan 2000 - Mar 2005

Slope of CERES vs MODIS: SW vs 0.64 μm



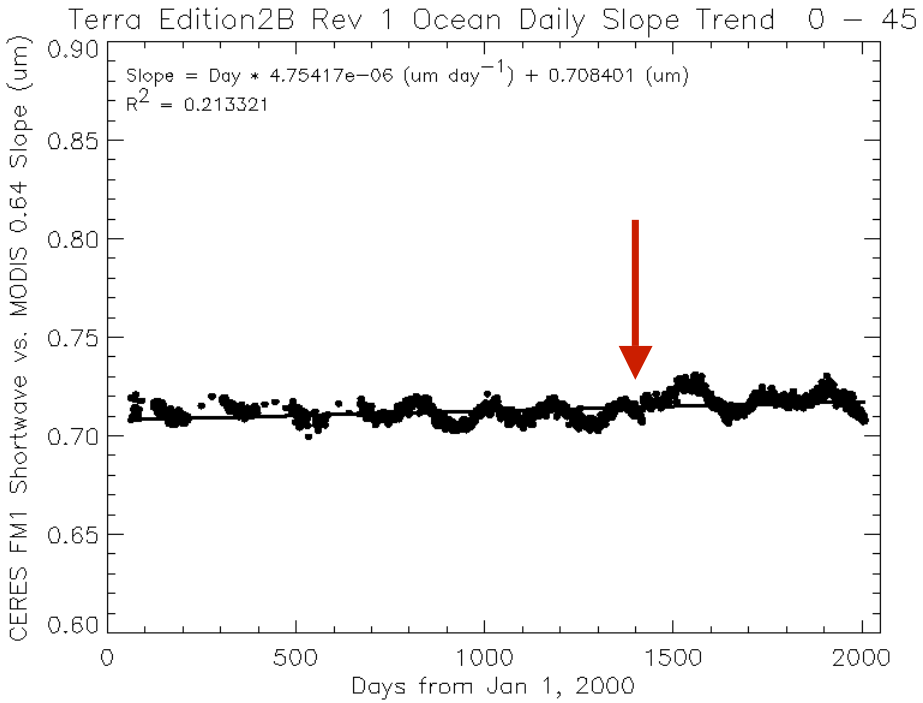


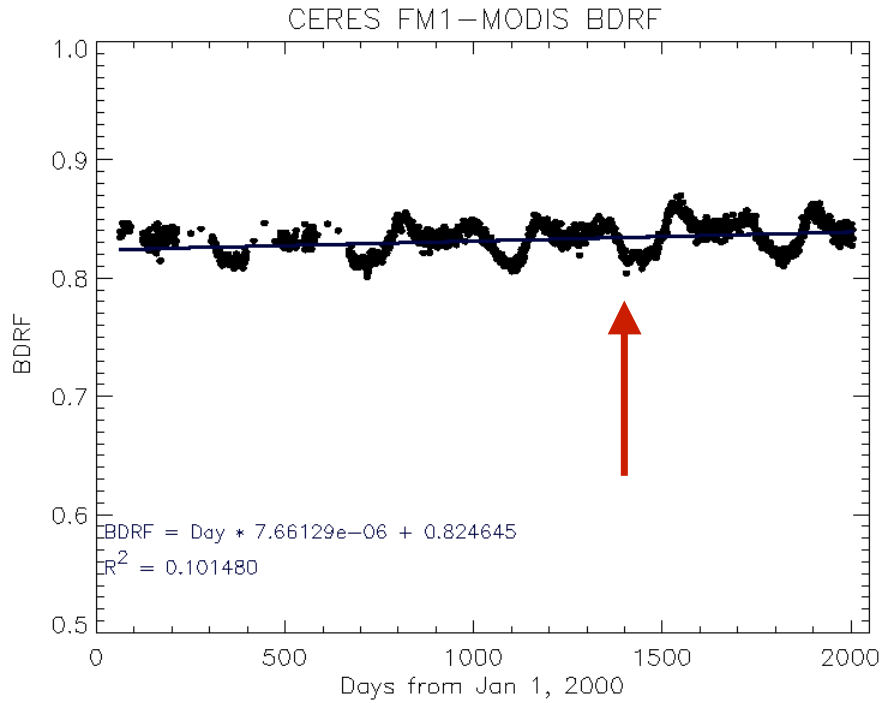
No trend for *Terra*; apparent trend for *Aqua*

Terra & Aqua MODIS may trend relative to each other

***Terra* darker than *Aqua* by 1.2% at start of 2003**

Comparison of CERES SW and *Terra* MODIS 0.635 μm, Jan 2000 - Jul 2005

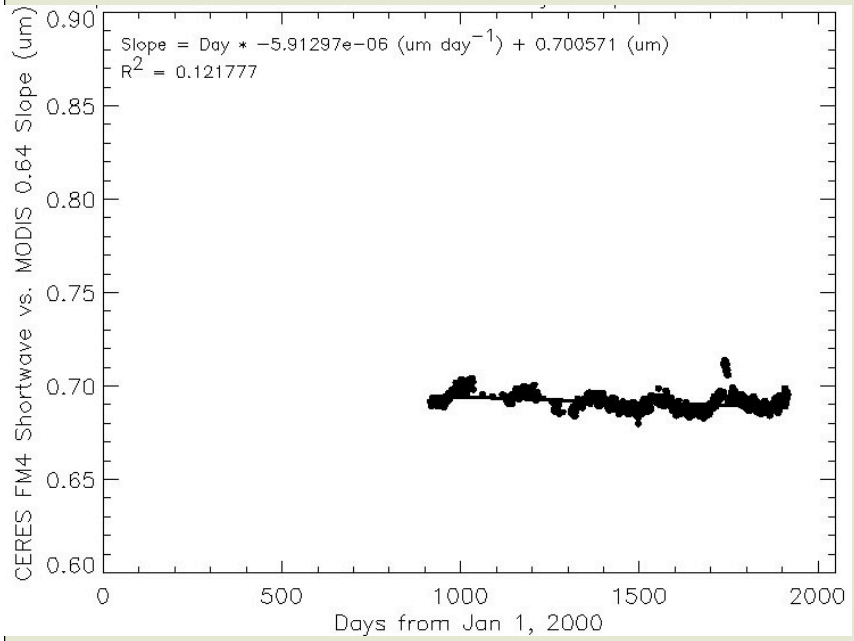




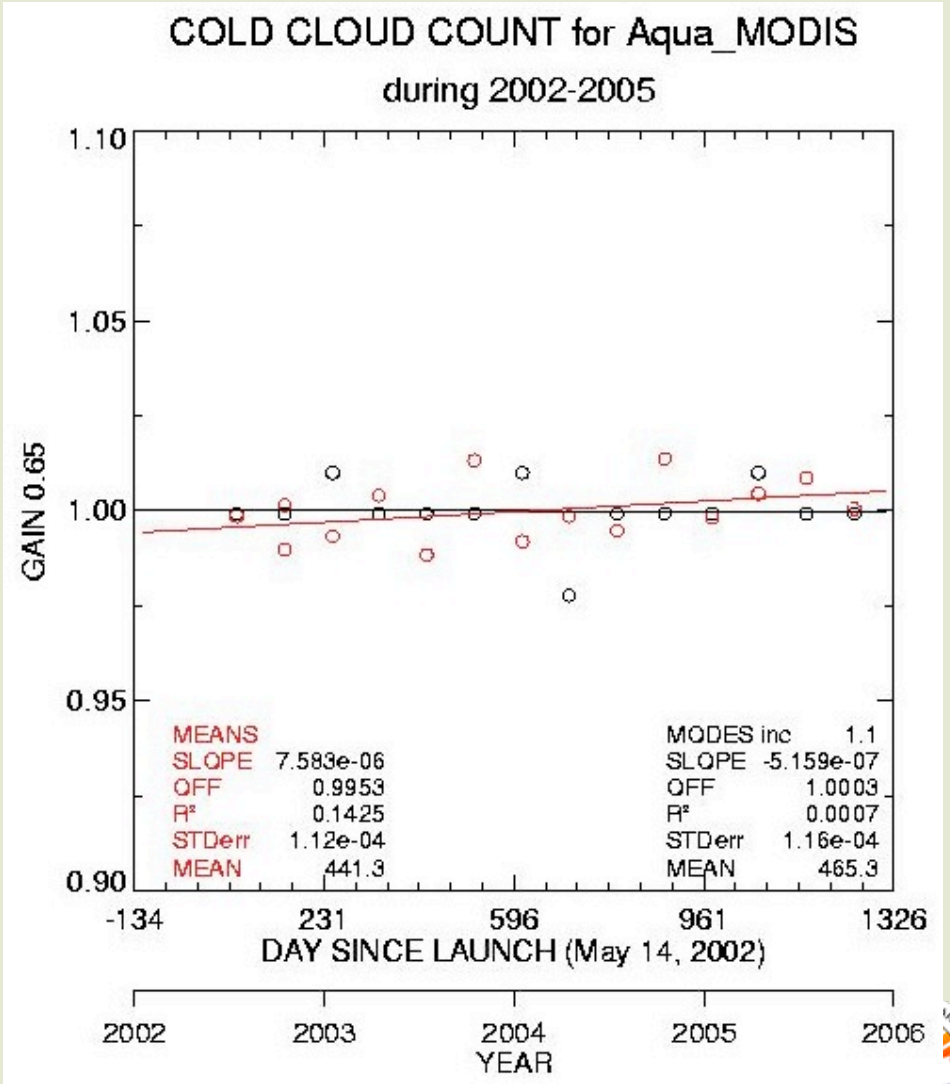
- **Terra discontinuity at day 1407, gain were tweaked.**
- **Any trends caused by sudden change in gain**

Aqua MODIS Trend
0.635 μm, July 2002 - Jul 2005

Aqua vs CERES

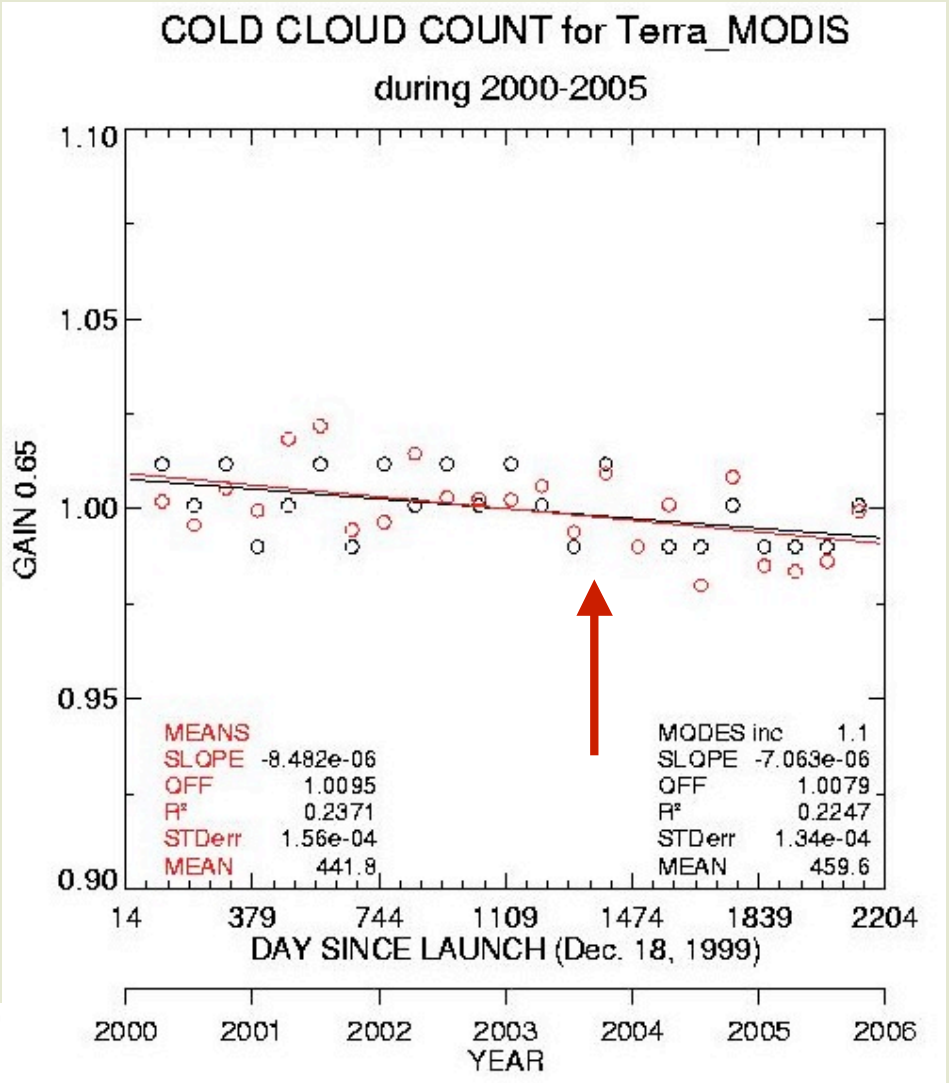


Aqua Deep Convective →



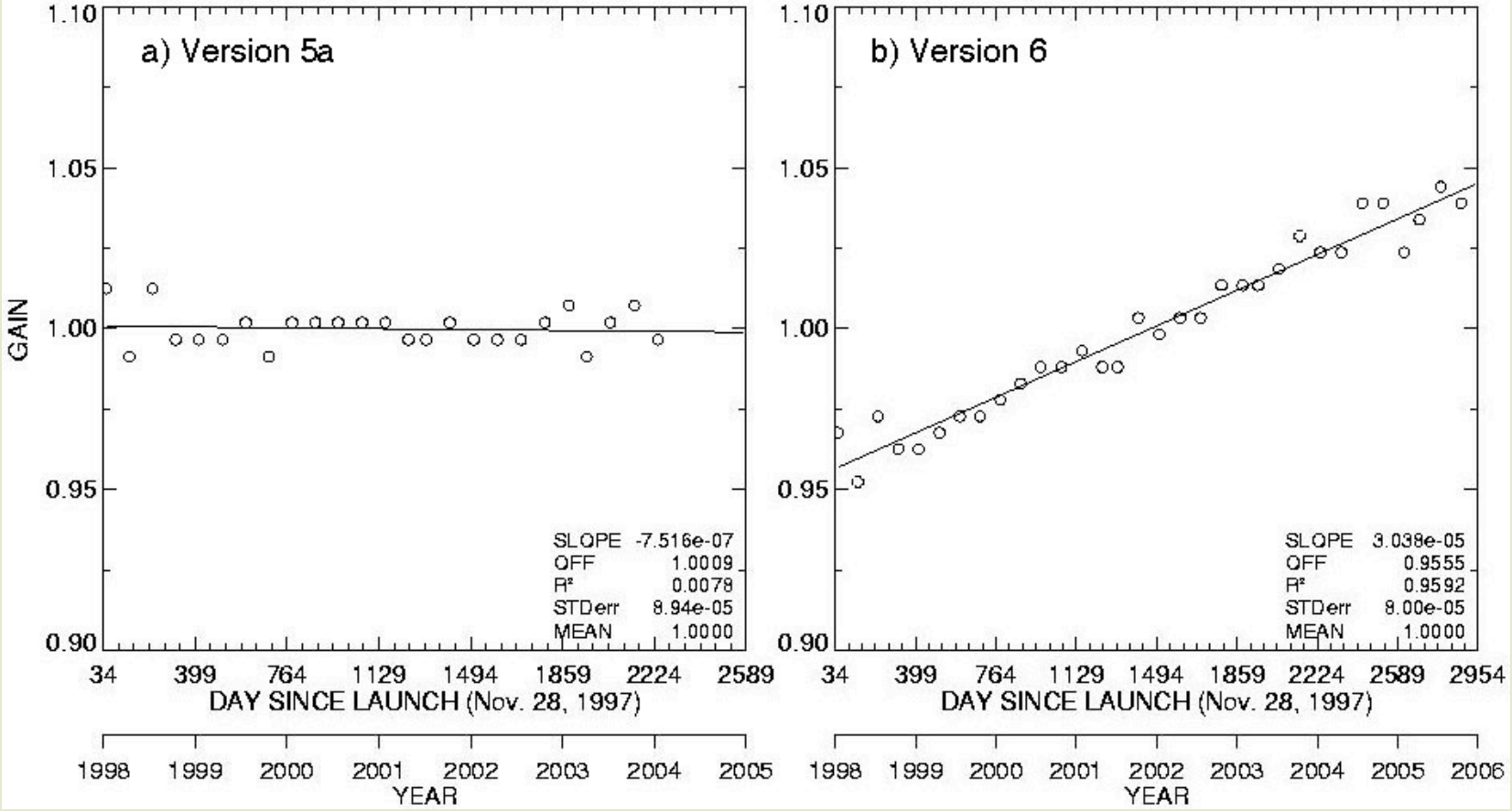
- **Aqua stable as a rock!**
- **CERES is degrading!**

Terra MODIS Deep Convective Trend
0.635 μm, Jan 2000 - Oct 2005



- Terra shows apparent trend
- Discontinuity causing it
- CERES is not degrading!

TRMM VIRS Deep Convective Trend
0.64 μm, Jan 1998 - Oct 2005

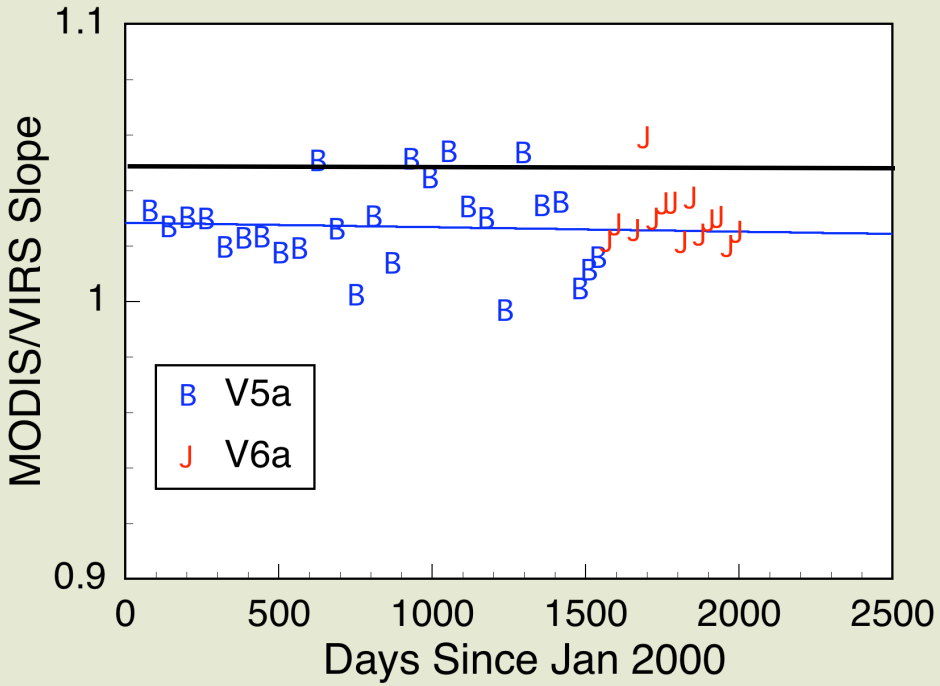


- V5a stable as Aqua
- VIRS lunar calibration took gain to see grandma

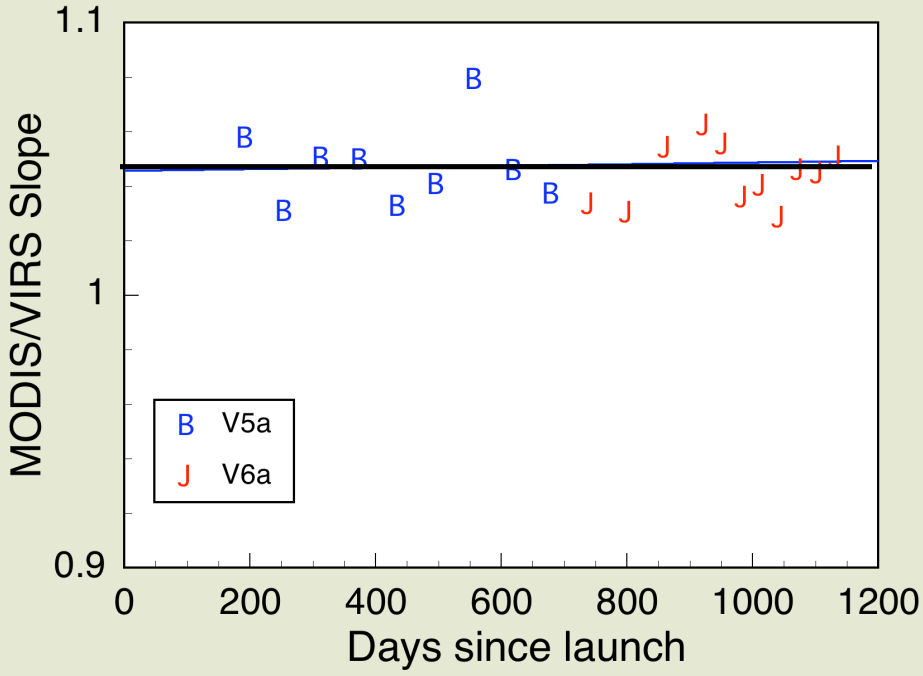
  - and she had big teeth!

Back to VIRS vs MODIS
0.64 μm, Jan 2000 - Jul 2005

VIRS vs Terra



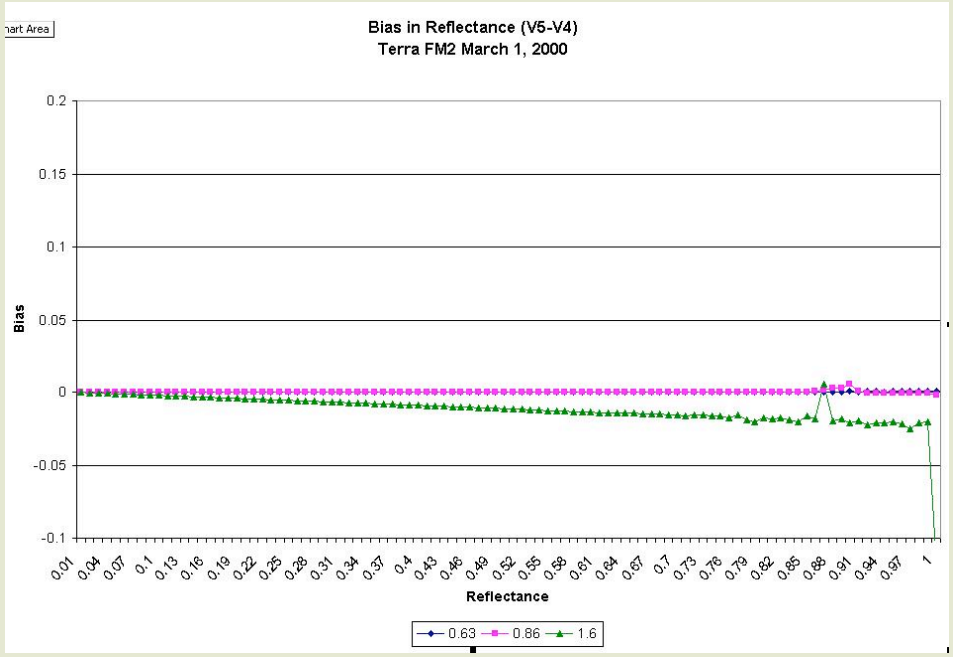
VIRS vs Aqua

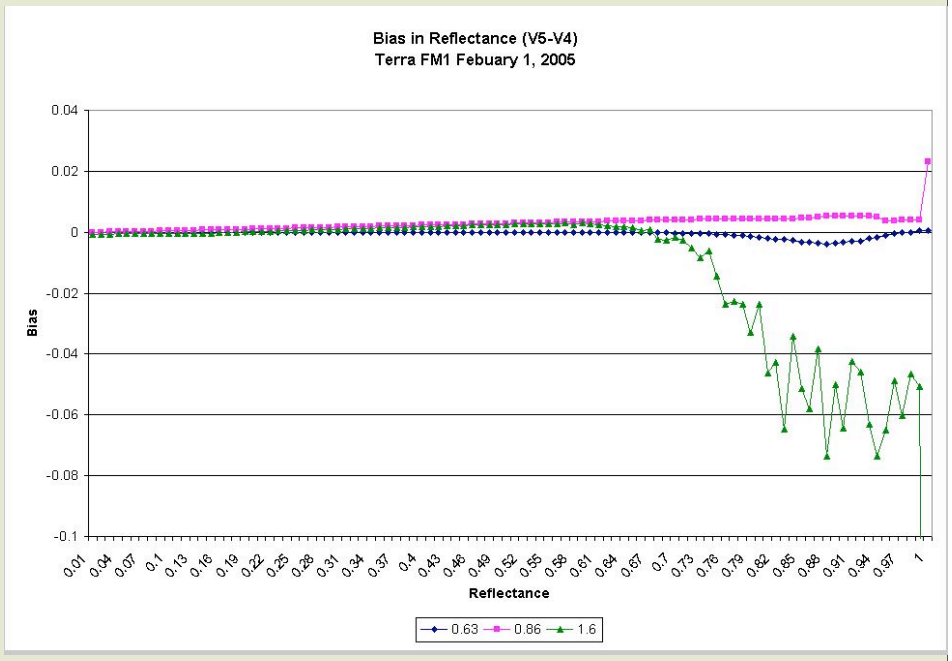


Theoretical slope over ocean is 1.048

- **V6 DCC correction aligns VIRS with both MODIS**
- **Aqua -VIRS in nearly perfect agreement with theory**
  - **Terra too dark!**

Help from Collection 5? Terra Solar Reflectance Channels



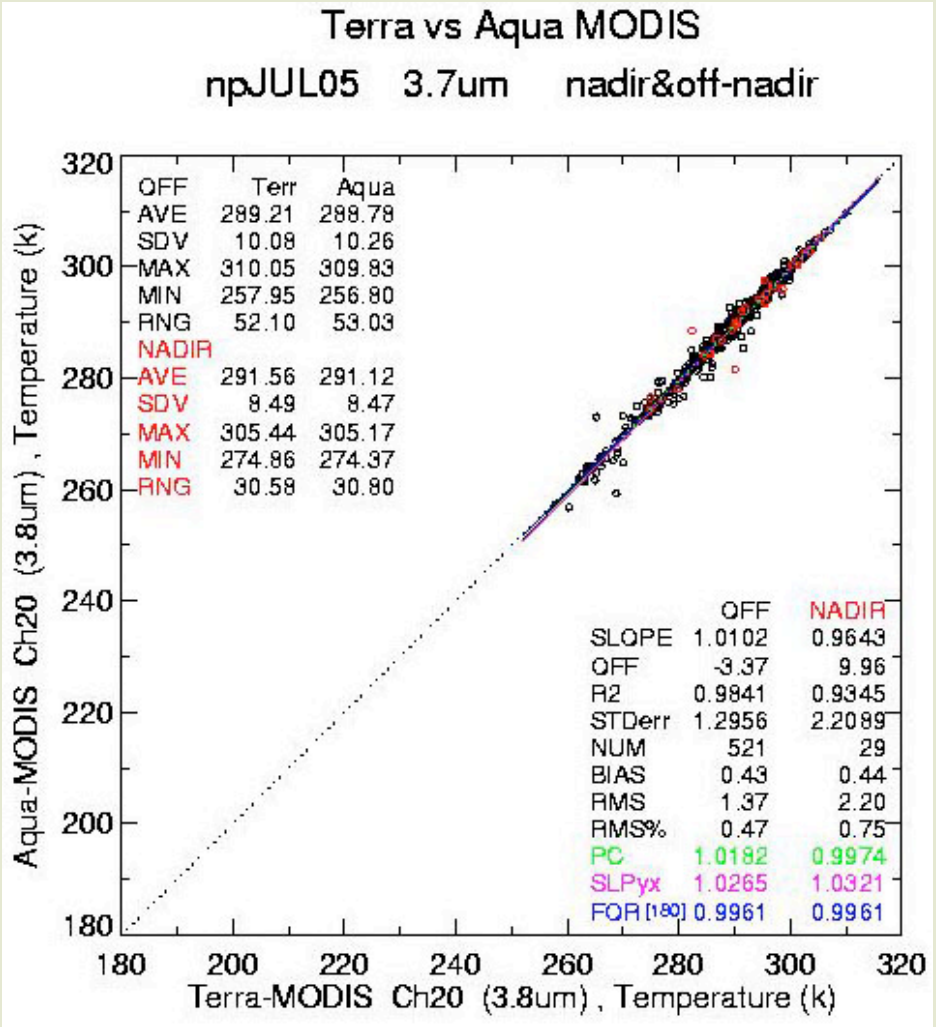


Collection 5 Seems to Darken Terra VIS channel

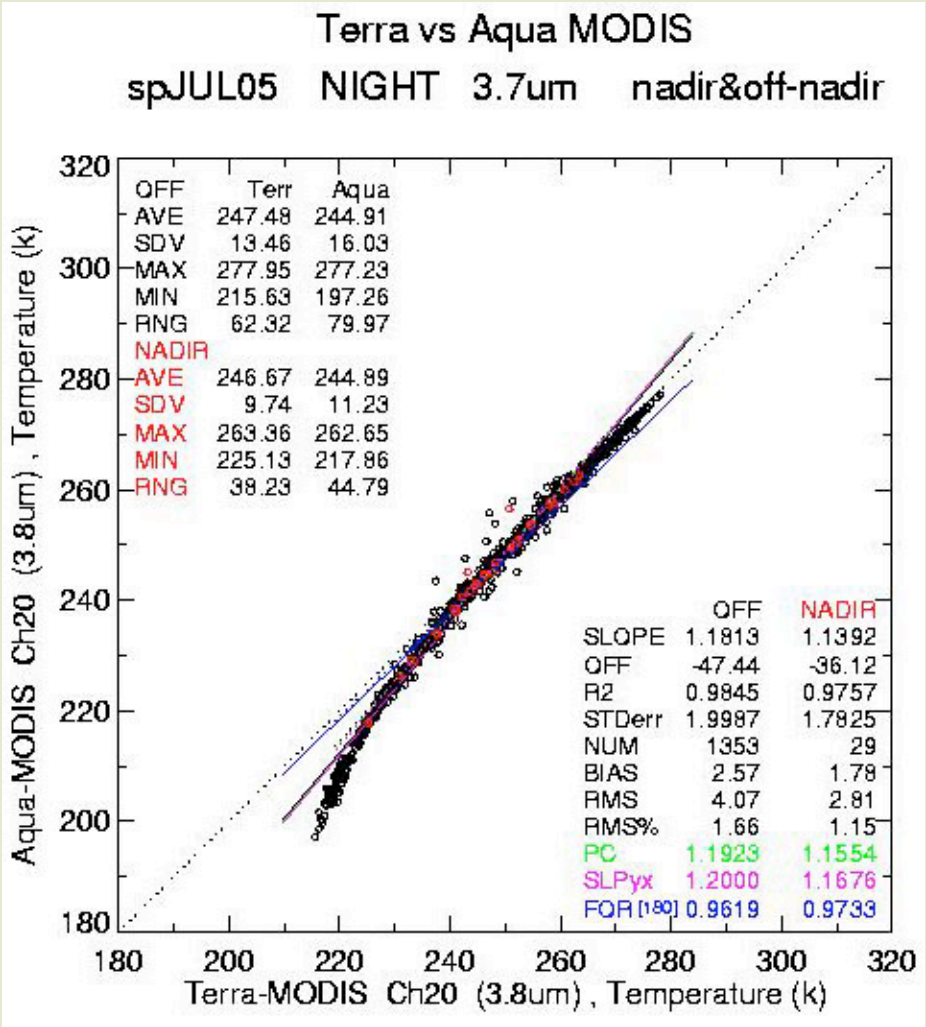
- **Propose to apply Aqua calibration to Terra for consistency and perhaps better absolute calibration**

Solar Infrared Channels

Daytime slope



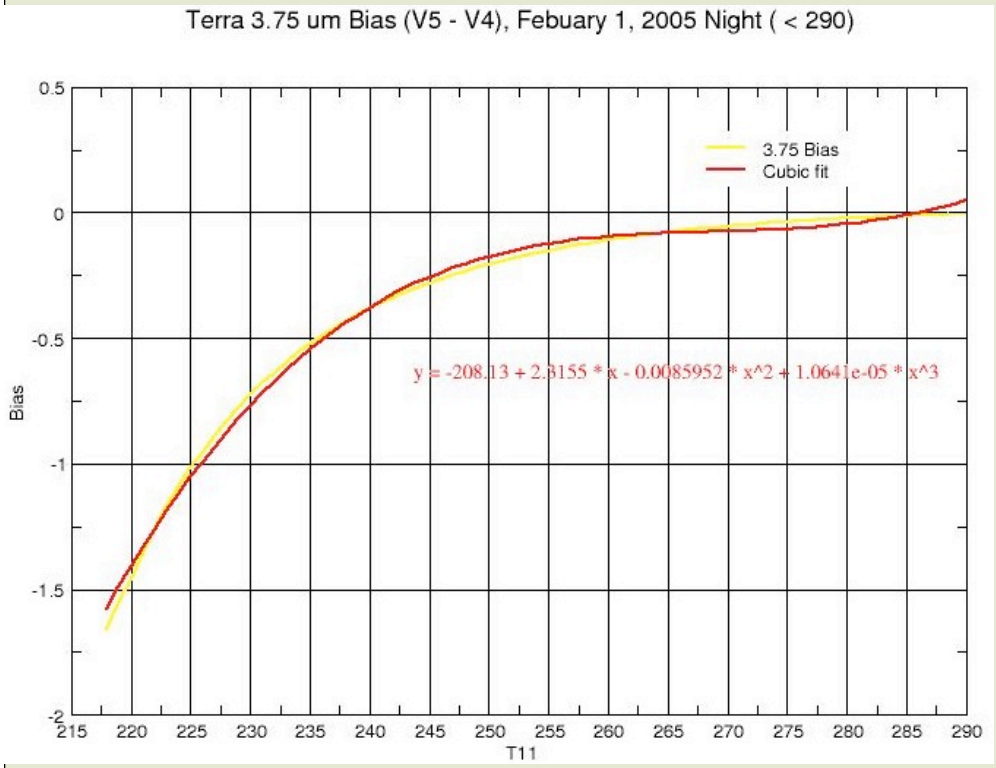
Night slope



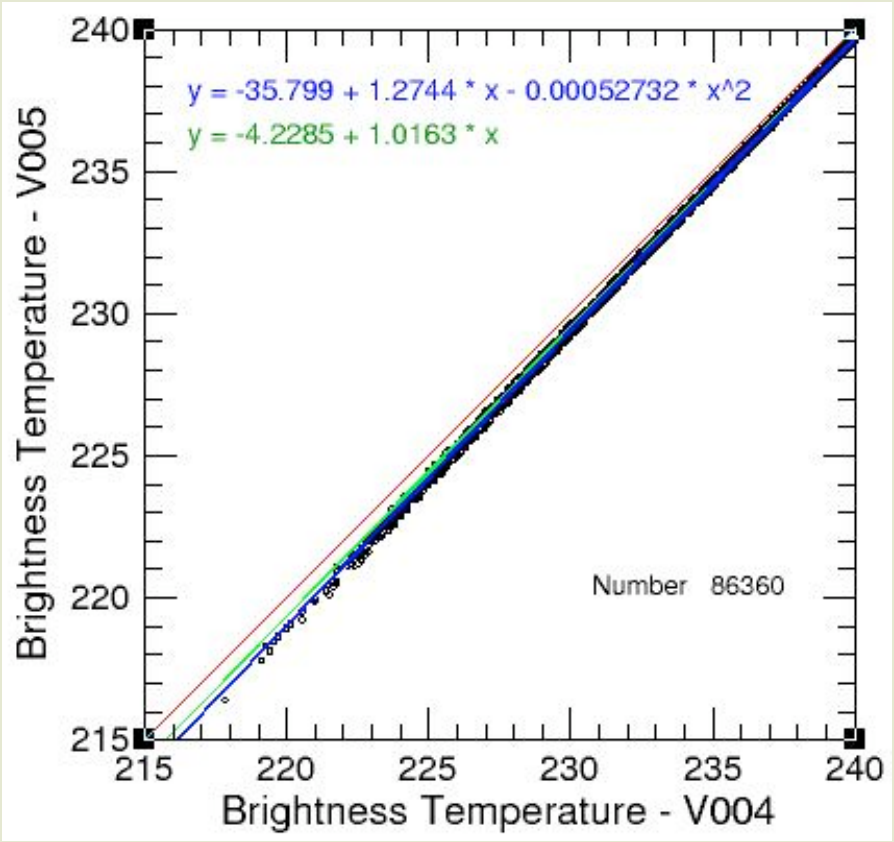
- **Aqua 0.57 K warmer than Terra during daytime**
- **Nonlinear difference at night at low temperatures**

Collection 5 Changes 3.8-μm CHANNEL

Collection 5-4 Difference

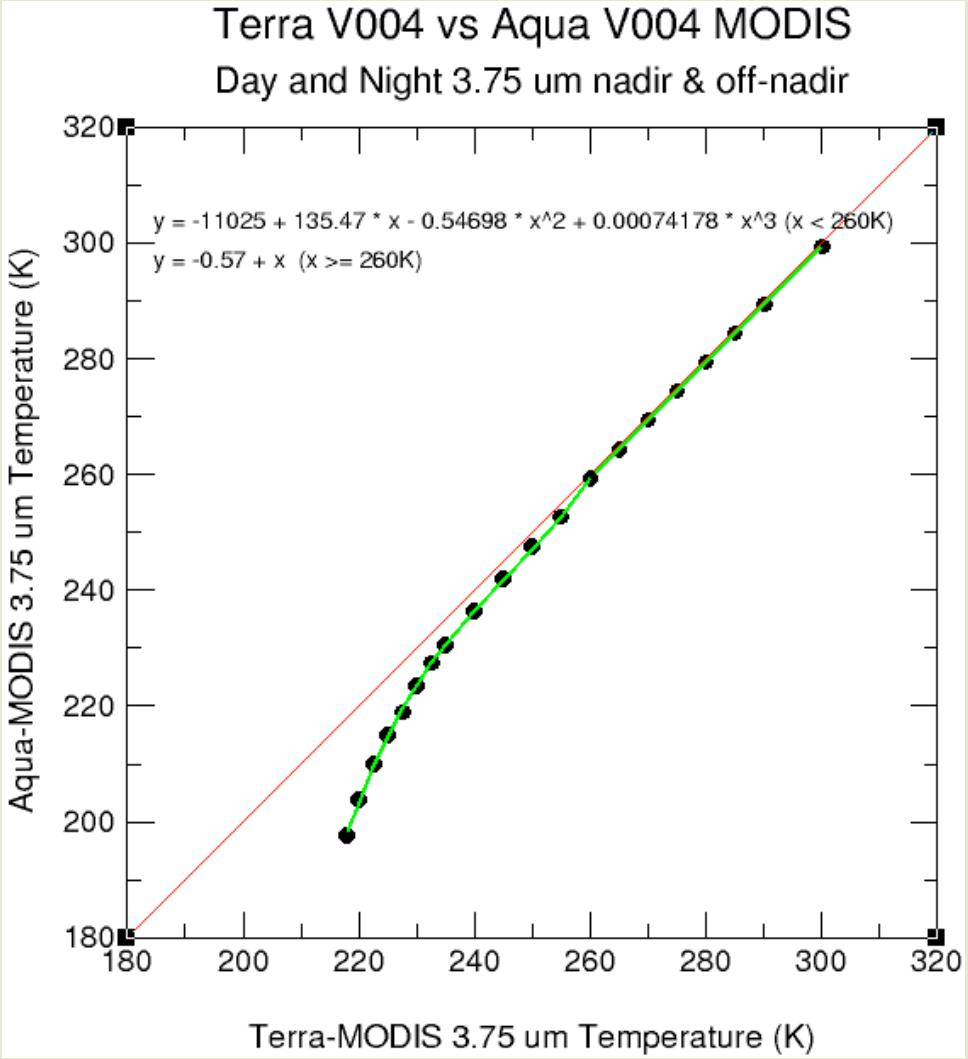


Correction Equation



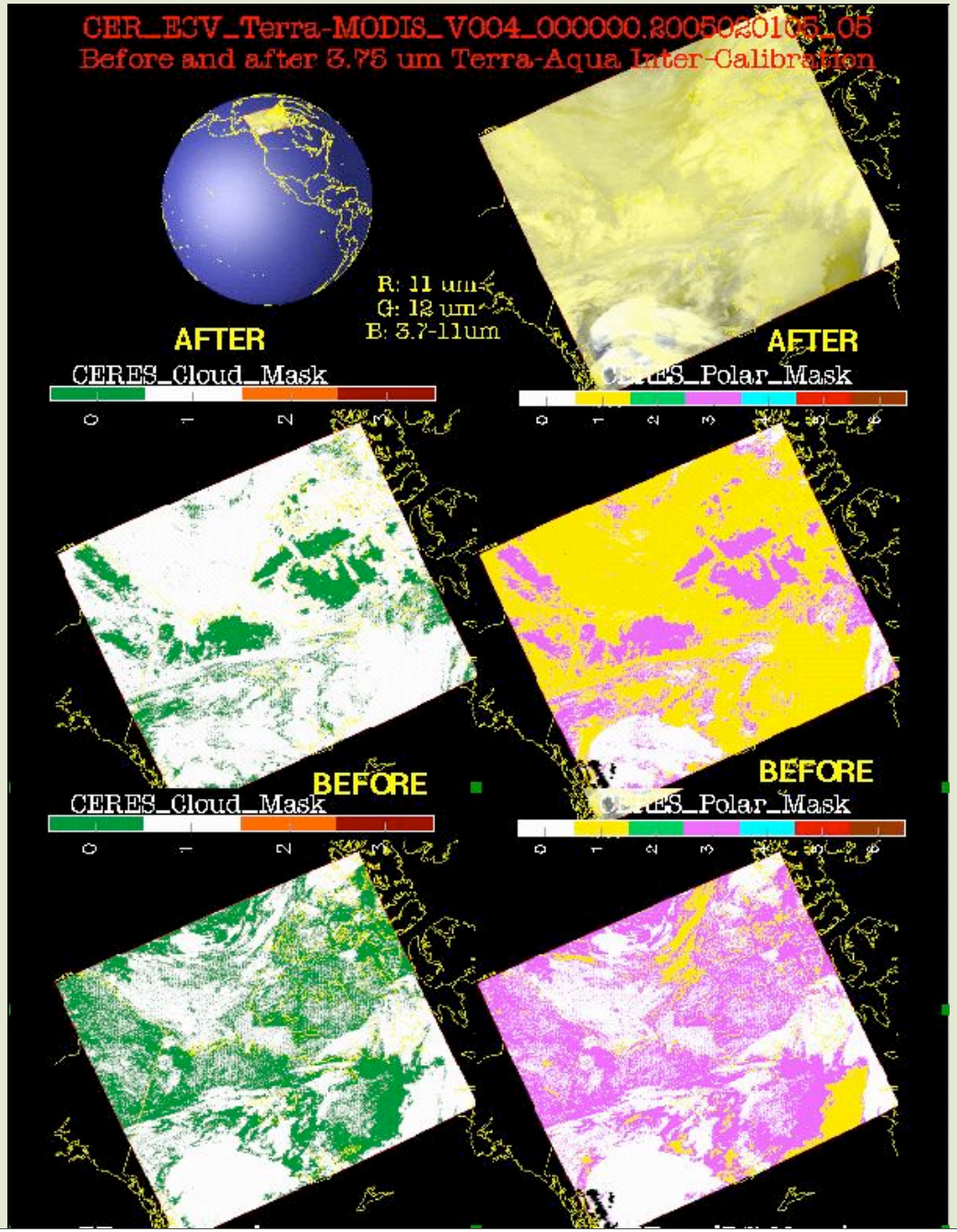
- Collection 5 will reduce some of the night difference, not daytime 0.5 bias
- Difference much greater at low temperatures

Proposed Terra 3.8-μm Calibration Change



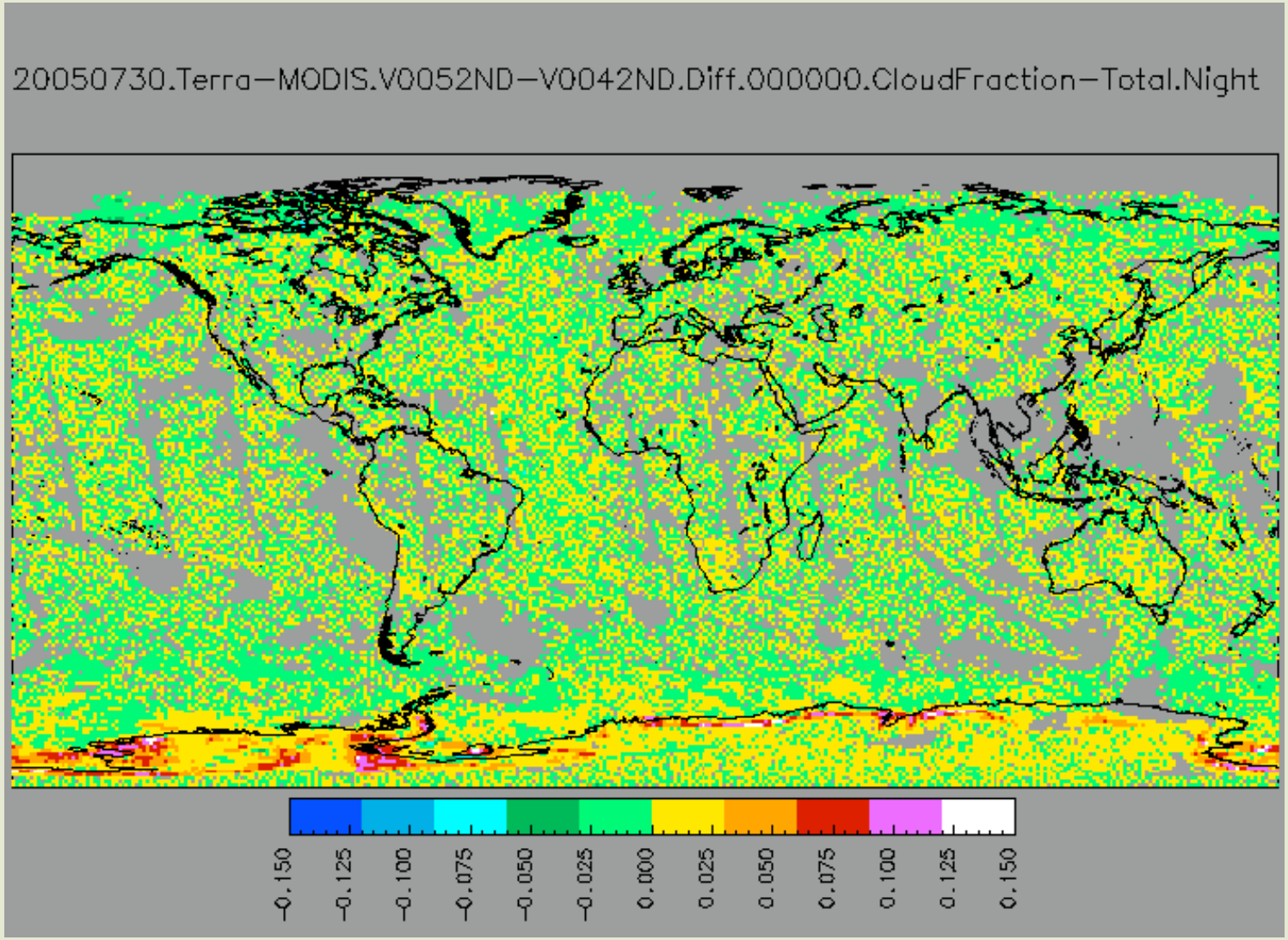
- Captures differences with Aqua and VIRS
- Might be time dependent
- Will increase daytime re by 0.5 -1 μm
- Will require normalization to Collection 5 data

Initial Test of Aqua 3.8-μm Calibration on Terra Polar Mask



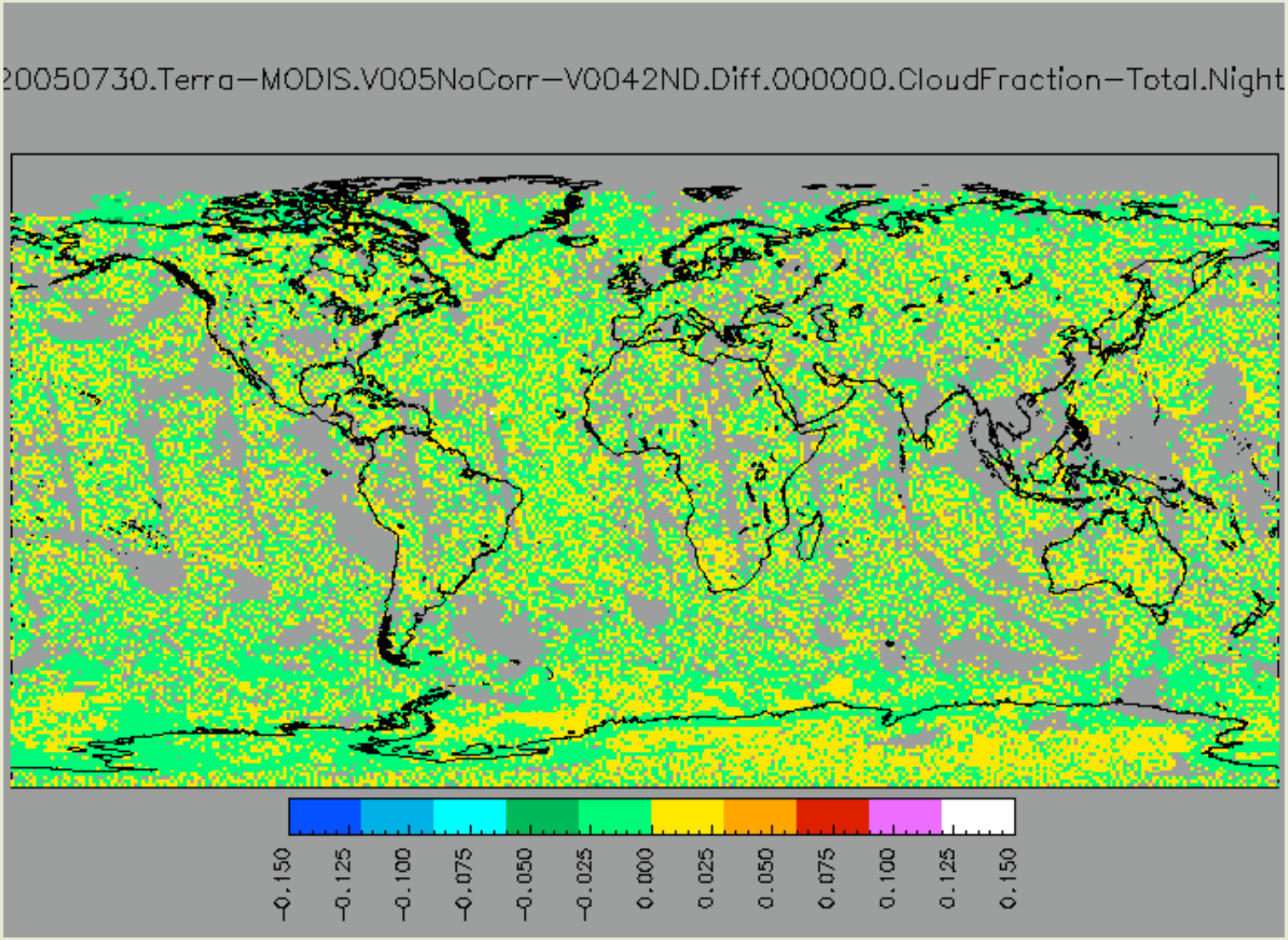
- More clouds detected, but some missed & new false ones, maybe
- More testing ahead

IMPACT OF COLLECTION-5 3.8-μm CALIBRATION ON NIGHTTIME MASK

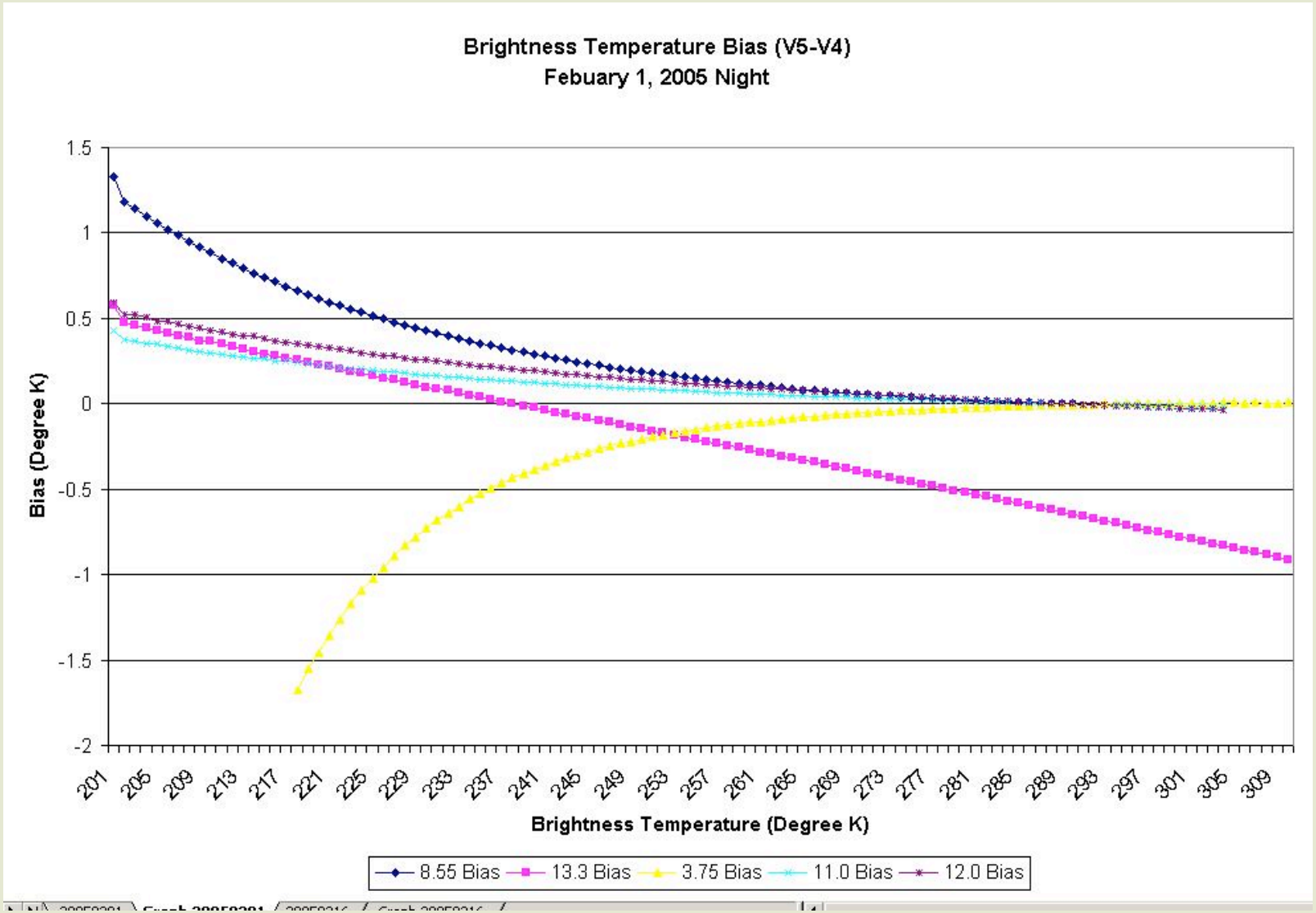


- **Use of Aqua calibration will cause much greater changes in polar regions**

Impact of Version 5 on Cloud Properties Using Current Algorithms



More Examples of Collection 5 IR Calibration Changes



Terra MODIS Collection 5 in Ed3

- Each channel calibration slightly different than Version 4
  - supposedly better

- Still testing Collection 5 to determine how much the cal differences vary and impact the results

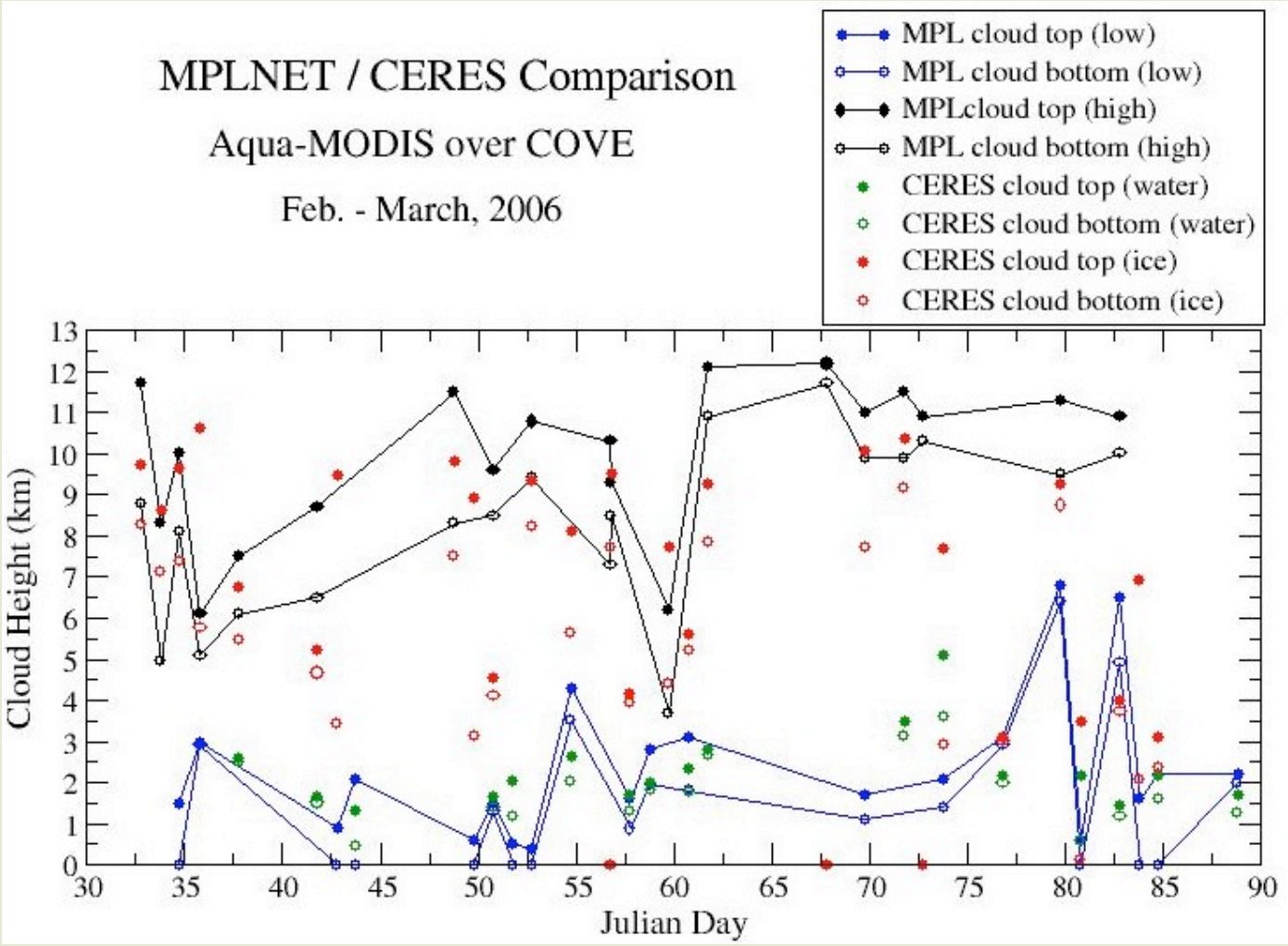
- Will thoroughly evaluate use of Aqua 0.64 & 3.8-μm calibrations for Terra

- Anyone using VIRS V6 data should apply DCC correction to bring it back to V5

VALIDATION

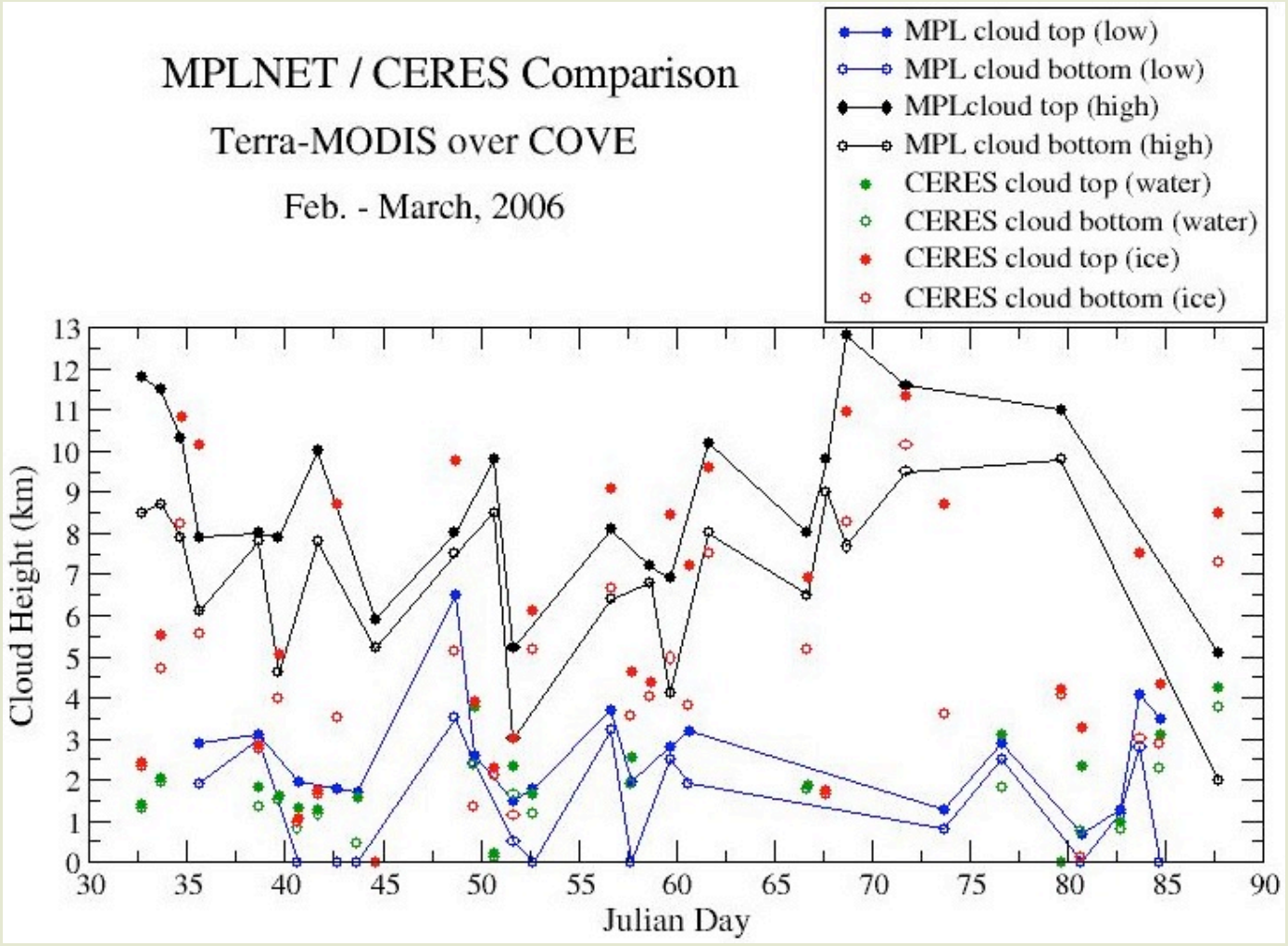
- New Results at COVE site
- More proxy comparisons
- The mystery of LWP

Cloud Heights at COVE, Aqua

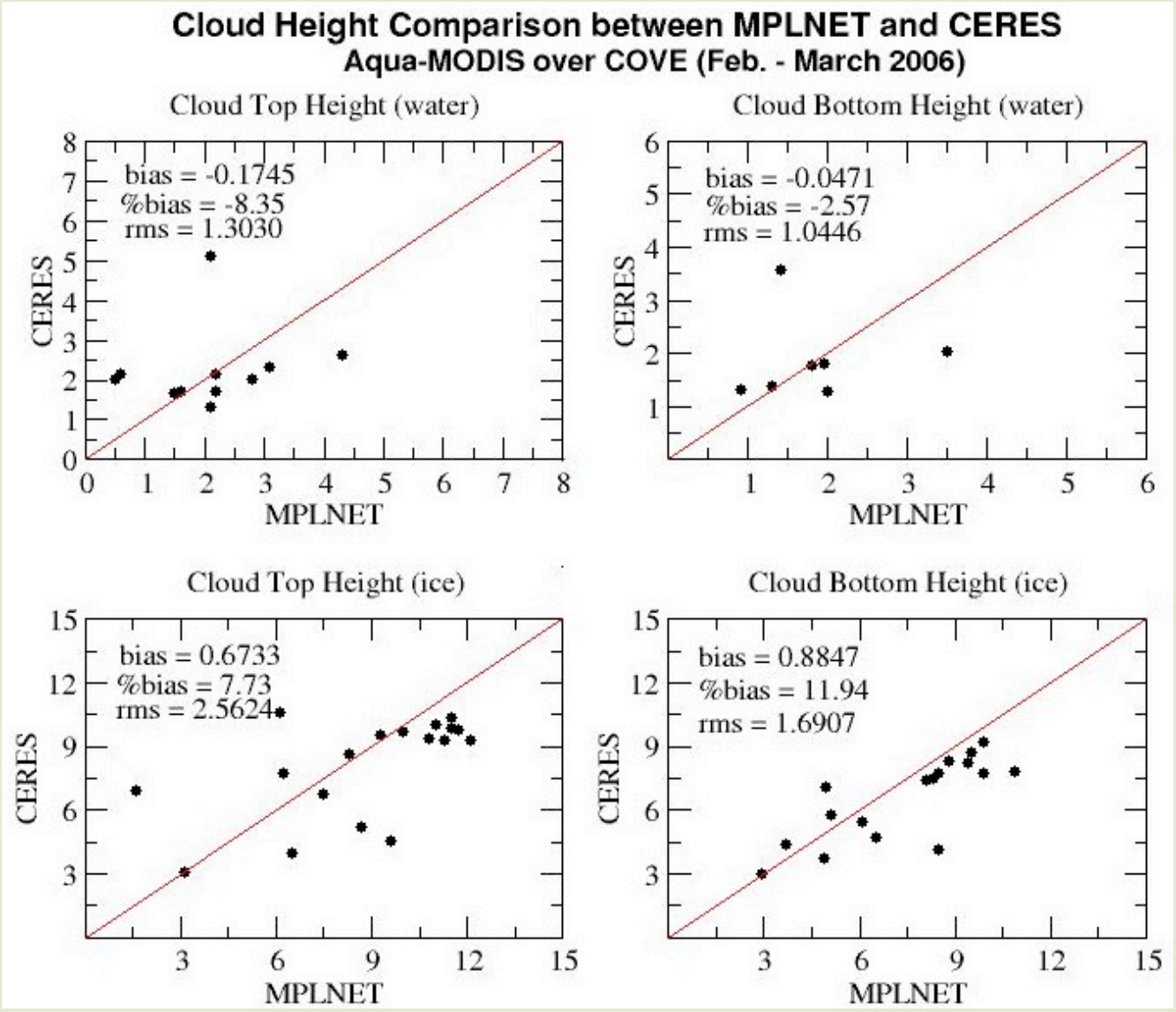


- **Limited comparisons due to lack of radar**
- **Multilayer clouds appear to produce worst heights in cirrus**

Cloud Heights at COVE, Aqua

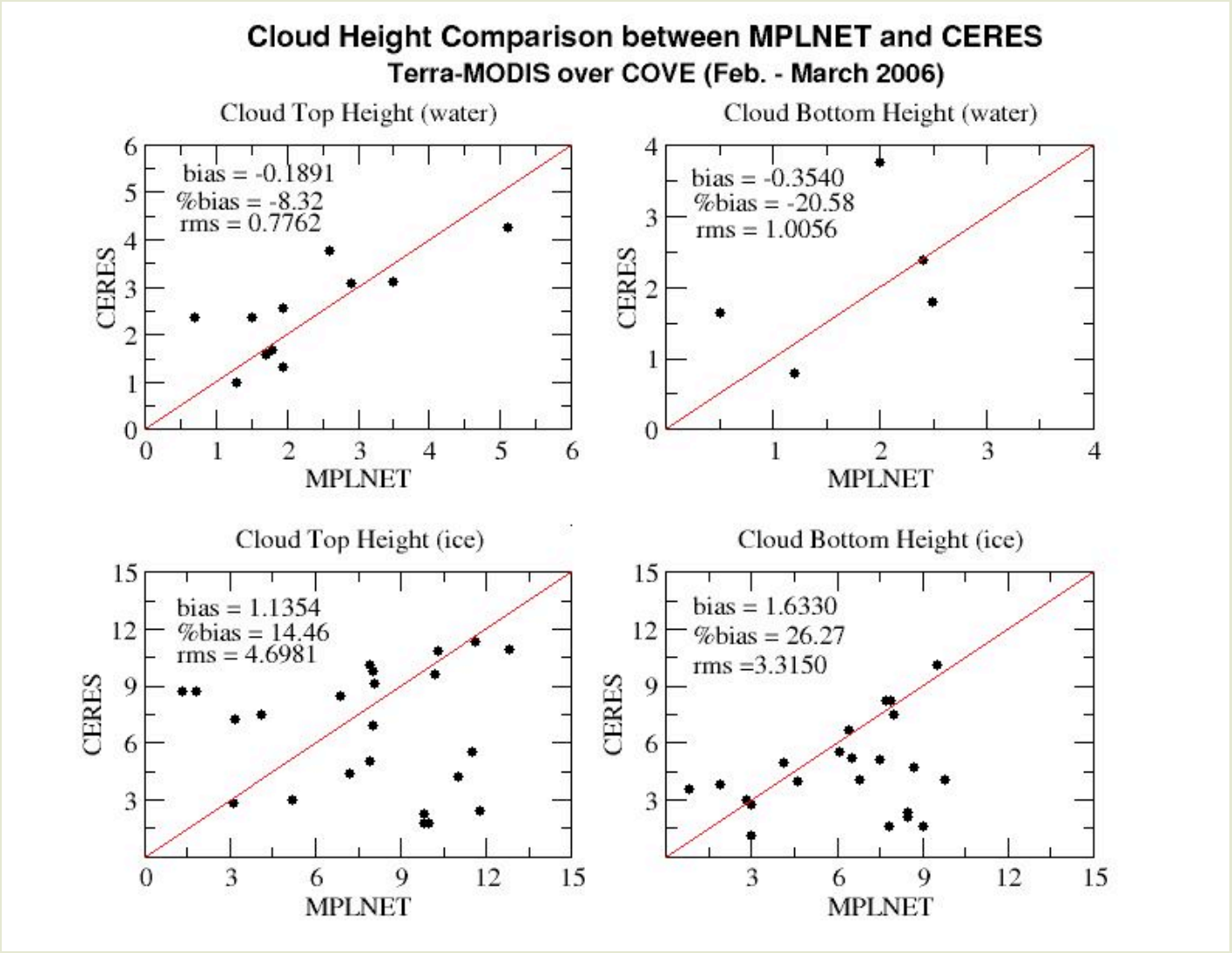


Summary of Aqua-COVE Height Comparison



- Low clouds essentially unbiased on average
- Ice clouds a little better than over land sites

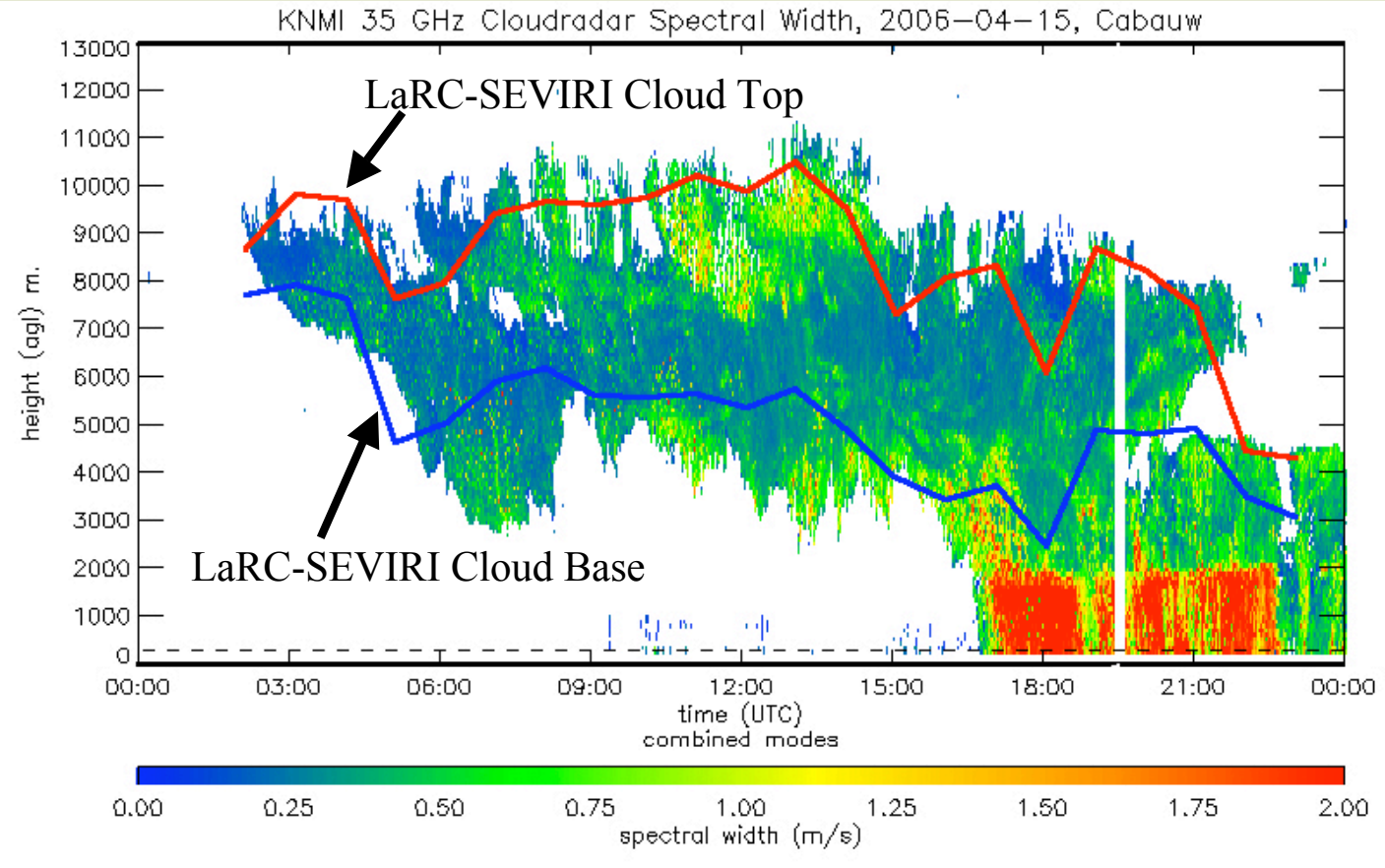
Summary of Terra-COVE Height Comparison



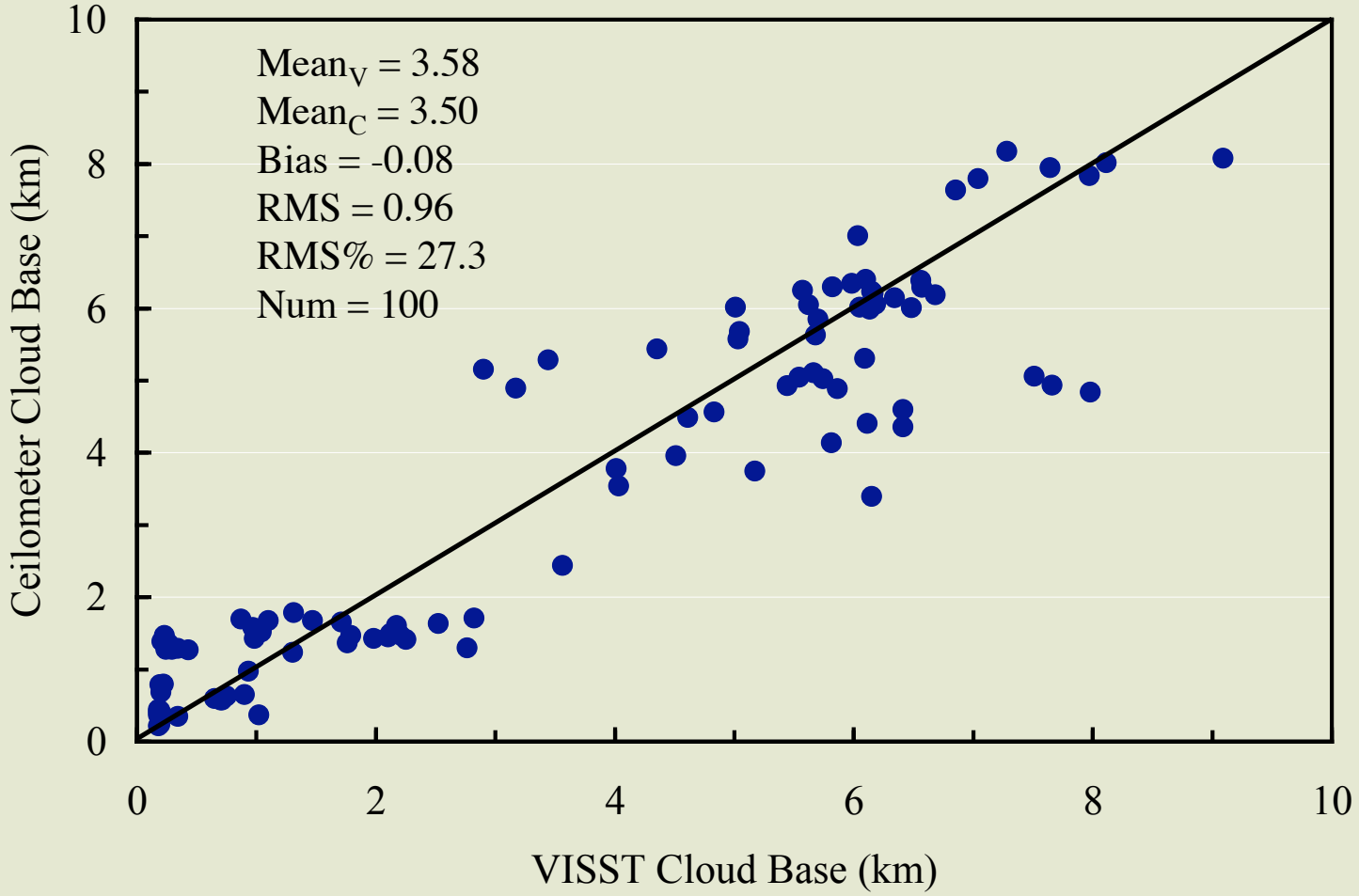
- Low clouds essentially unbiased on average
- Ice cloud errors similar to land sites

SEVIRI (CERES Algorithm) vs Surface Radar Cloud Heights

Cabauw, Netherlands Radar Comparison (4/15/2006)



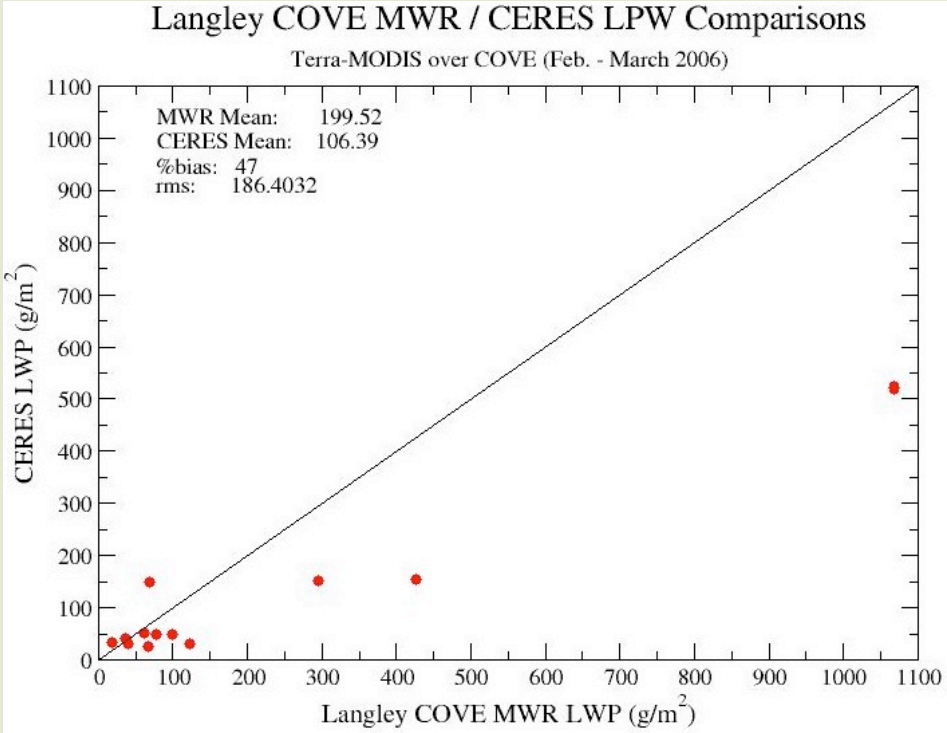
Ceilometer Cloud Base Height Comparison
Chilbolton, UK (January - March, 2006)



- Repeat comparisons with matched CERES MODIS products
- Expect to include Cabauw & SIRTA + Chilbolton

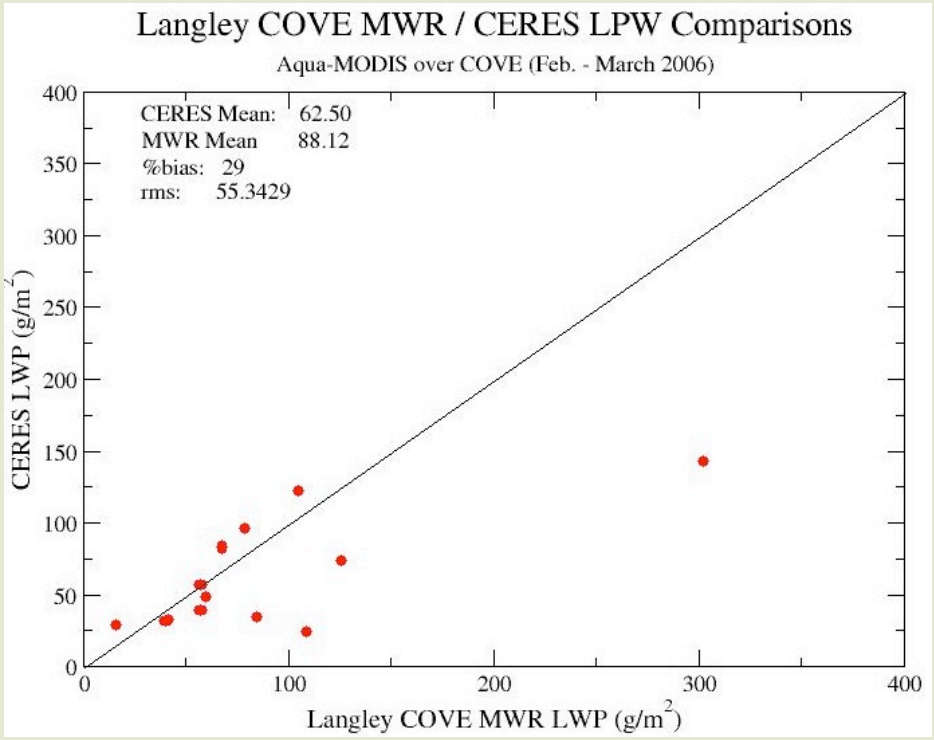
Summary of Preliminary Terra-COVE LWP Comparison

Terra



Without largest value, bias = 24%

Aqua



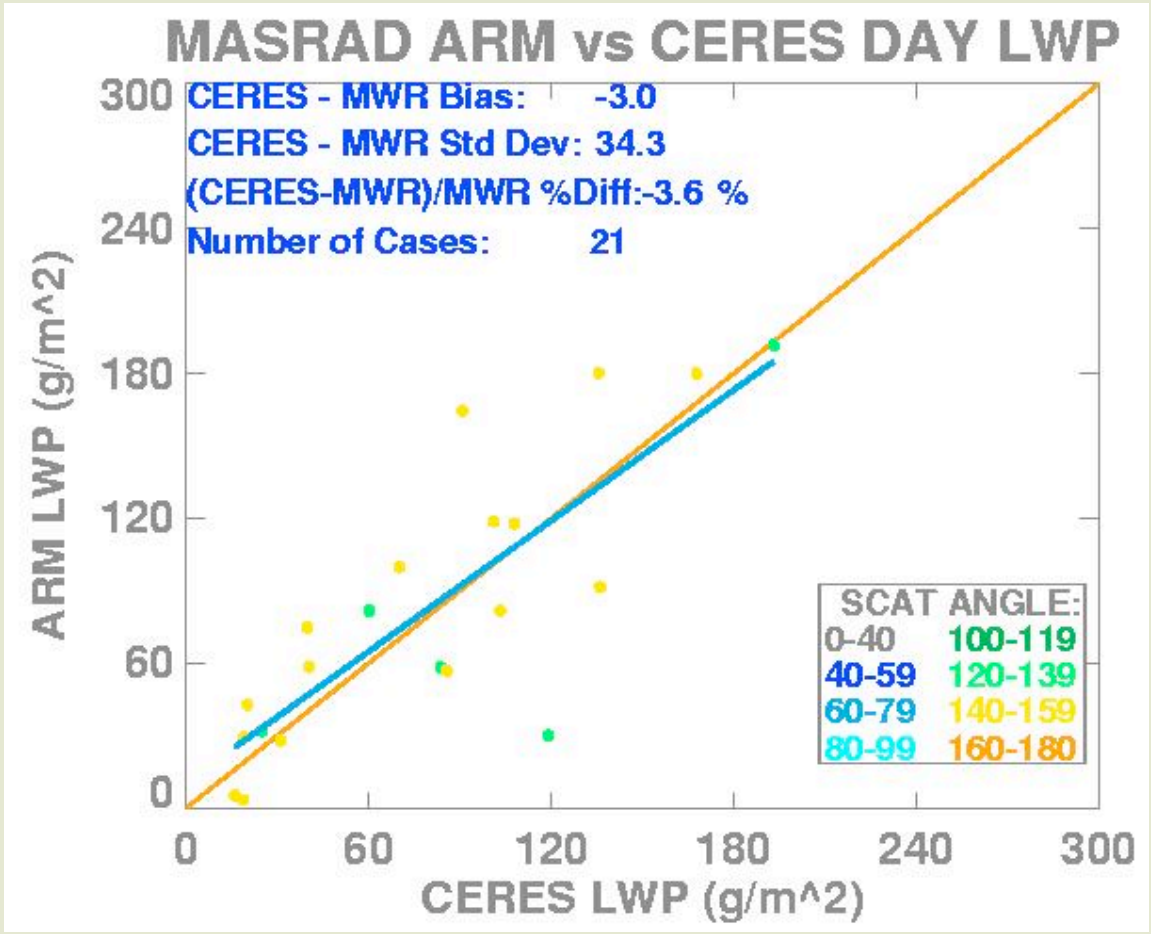
Without largest value, bias = 4%

- **Values < 200 gm^{-2} compare well.**
- **Data not screened for ice clouds and inhomogeneities**
- **Not certain of MWR quality for large LWP**

Terra Validation over Ocean (beach) Site

LWP over ARM AMF site, Pt. Reyes, CA

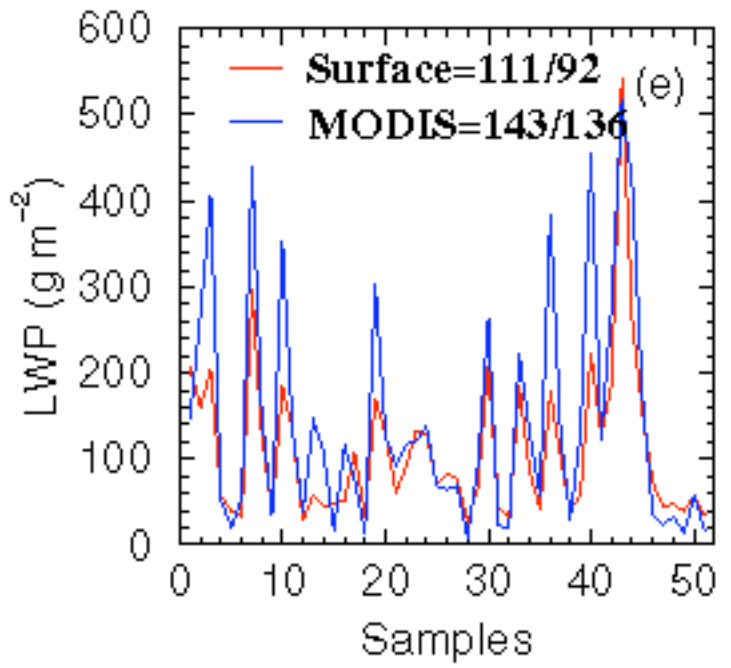
Feb 2005-June 2005

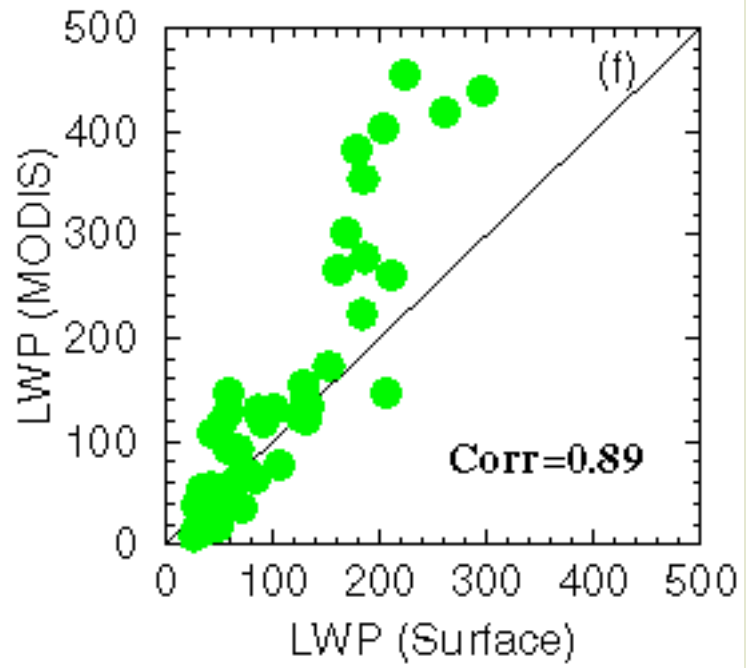


CERES very consistent with surface data

Aqua Validation

LWP over ARM SGP site, July 2002-July 2004





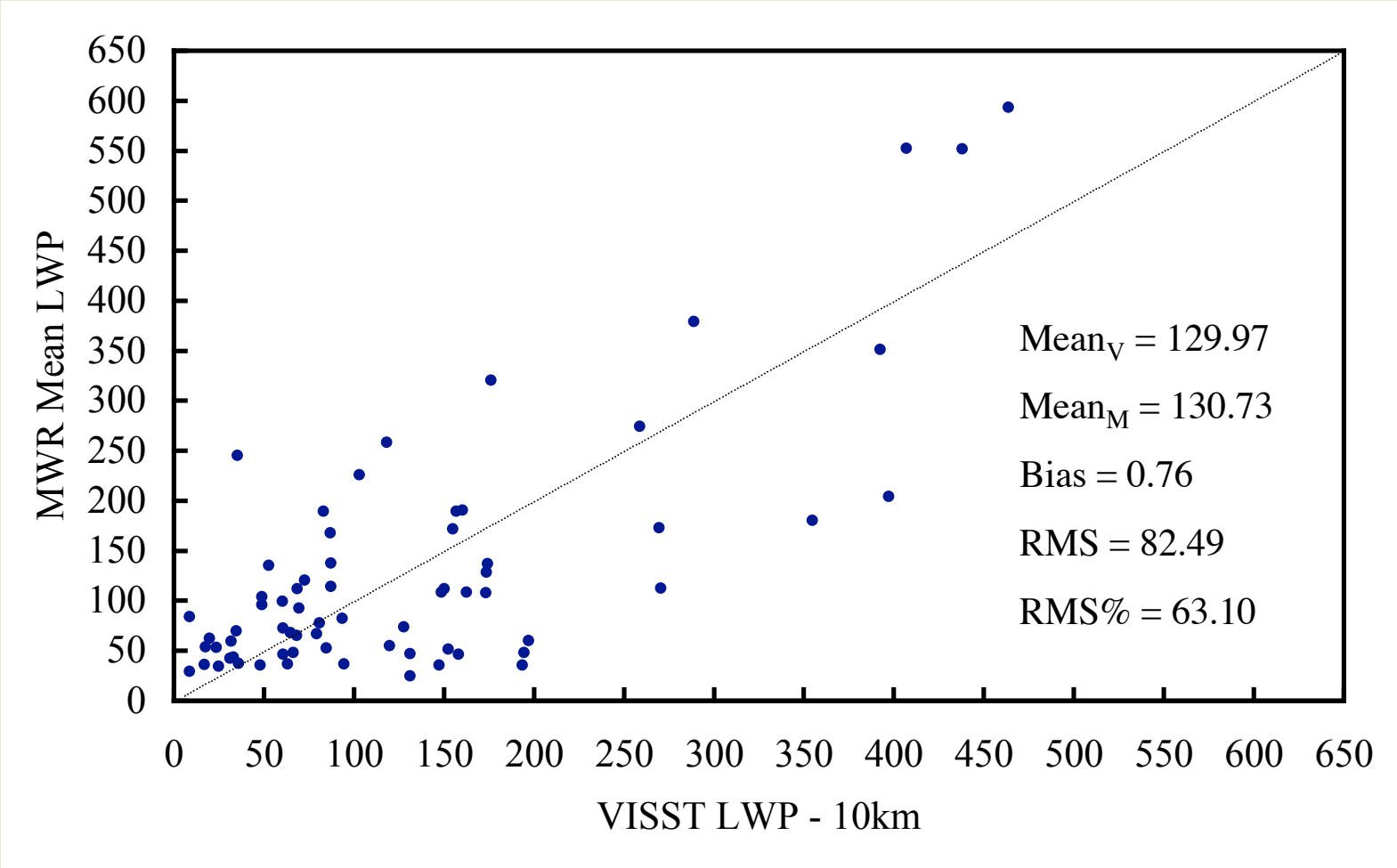
- **LWP:** VIRS + 16% ($r^2 = 0.96$)

  Terra - 18% ($r^2 = 0.88$) r_e too low, τ too low

  Aqua + 28% ($r^2 = 0.89$) τ too low

Standard errors ~ 50%

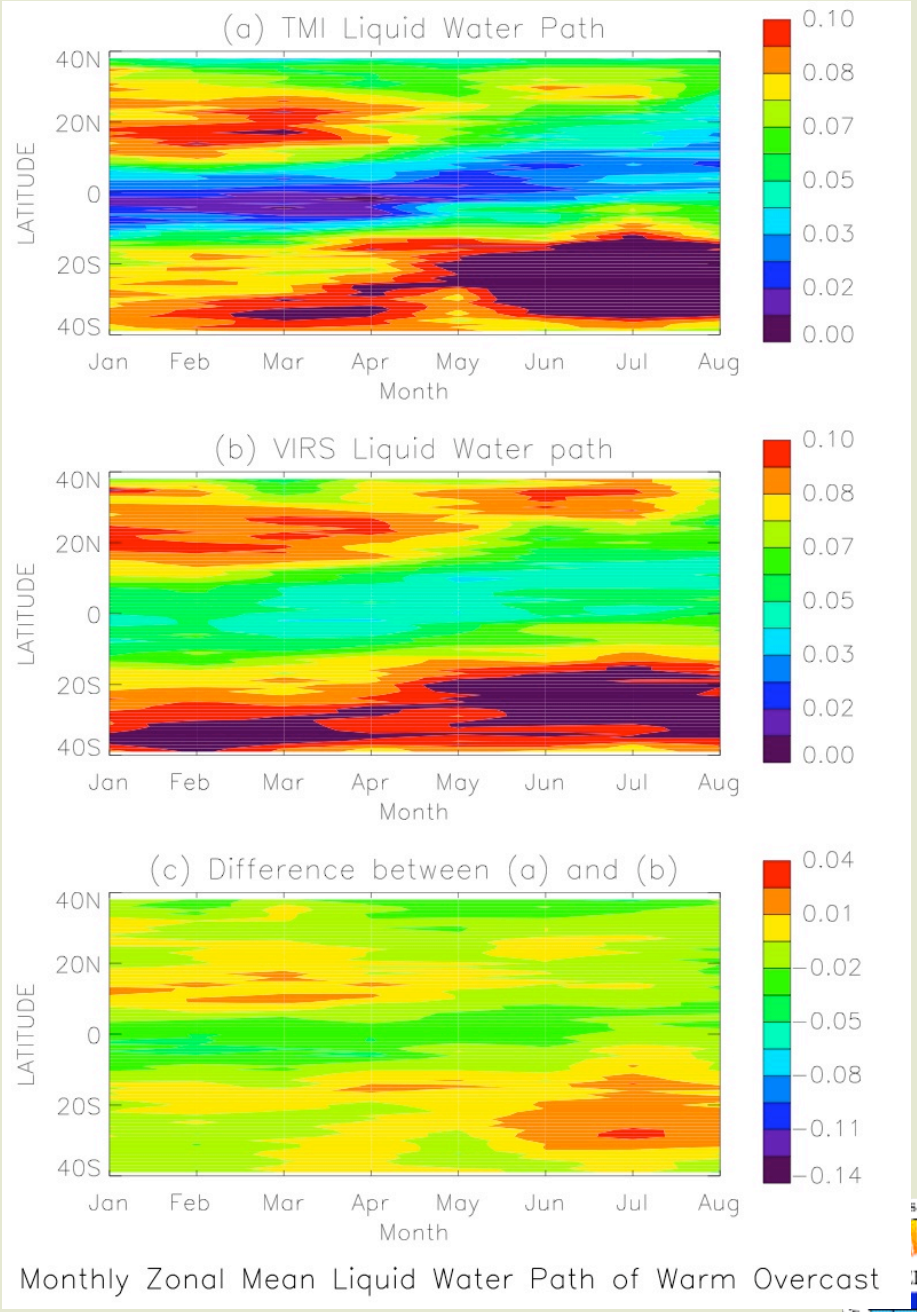
SEVIRI (CERES Algorithm) vs MWR LWP
Chilbolton, UK (January - March, 2006)



- Repeat comparisons with matched CERES MODIS products
- Expect to include Cabauw & SIRTA + Chilbolton

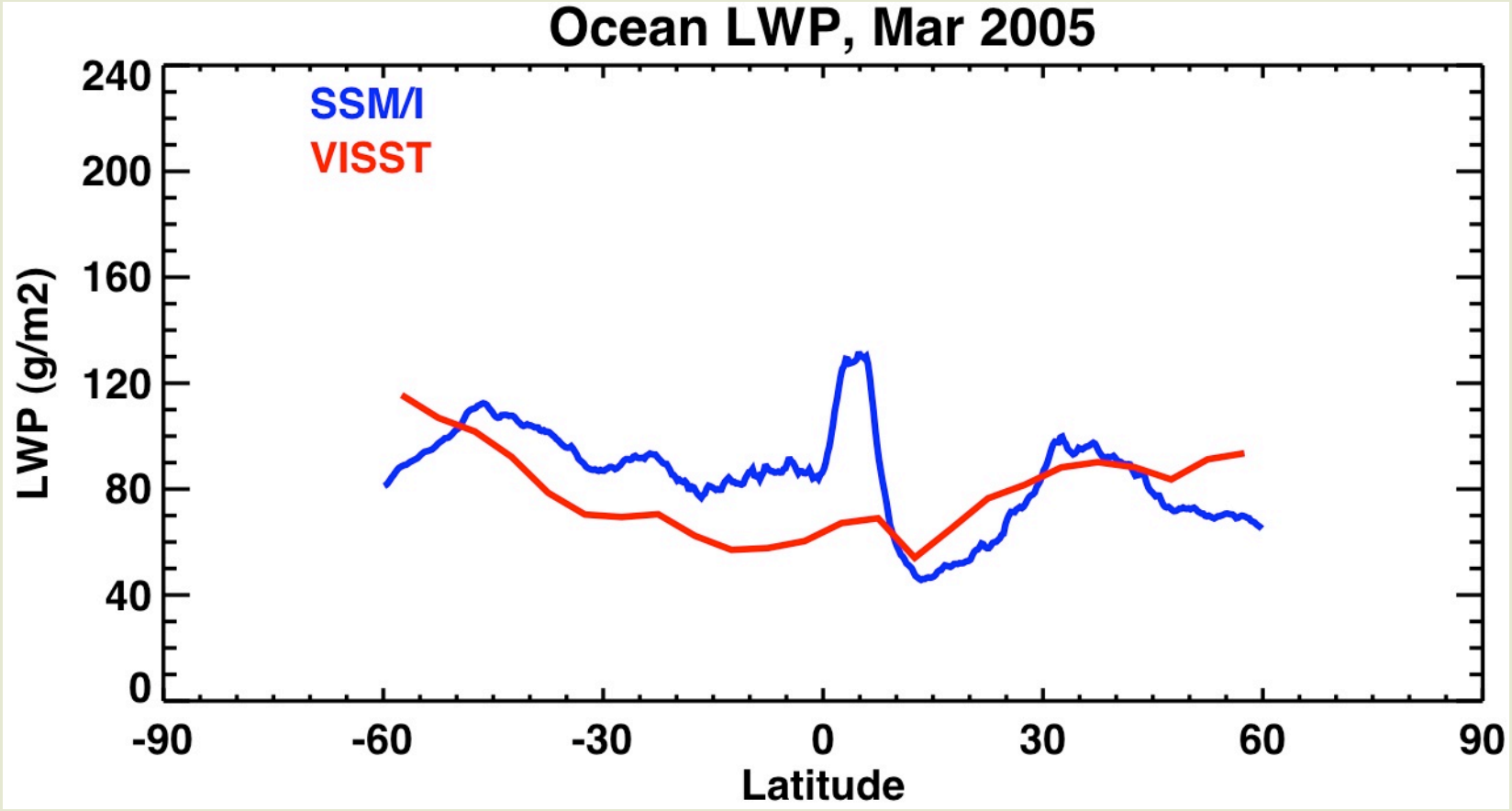
CERES VIRS vs TMI LWP
Monthly Zonal Means, 1998
Tc > 273 K

- VIRS > TMI in Tropics & summer hemisphere
- VIRS < TMI in winter subtropics
- VIRS generally larger than TMI, especially for cold clouds



CERES Aqua LWP vs SSM/I

All water clouds



- Aqua LWP < TMI in SH,
  - ice clouds blocking near Equator, but 5S - 50S?
- Diurnal cycle?

Diurnal Cycles of LWP from TRMM TMI

-Wood et al., GRL, 2002

Diurnal Cycle for small region

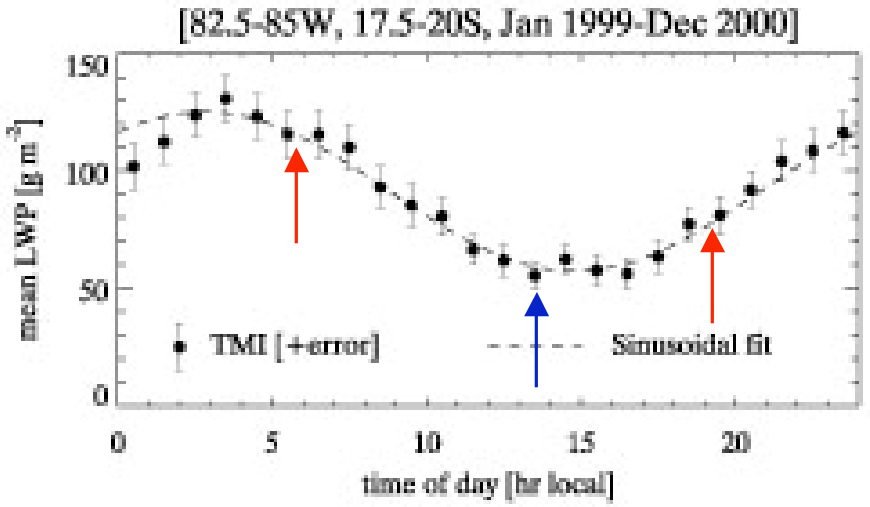


Figure 1. Example of two year mean diurnal cycle from the TMI for asingle 2.5 × 2.5° region in the SE Pacific, showingsinusoidal fit to data.

Amplitudes for large regions

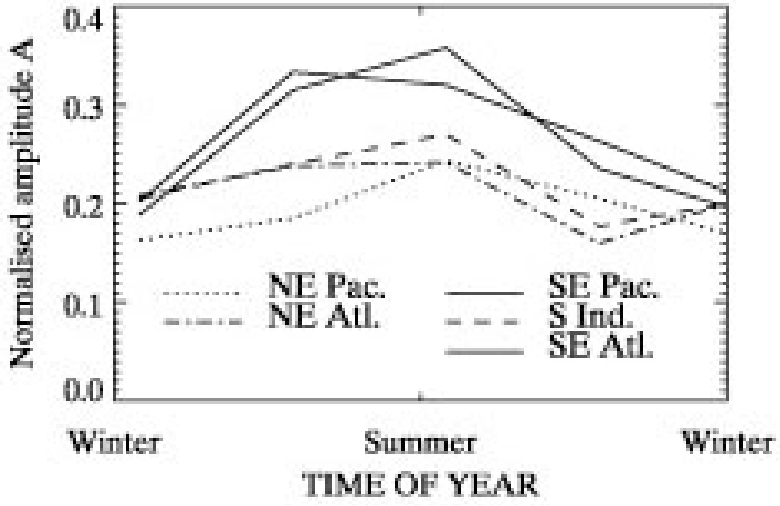
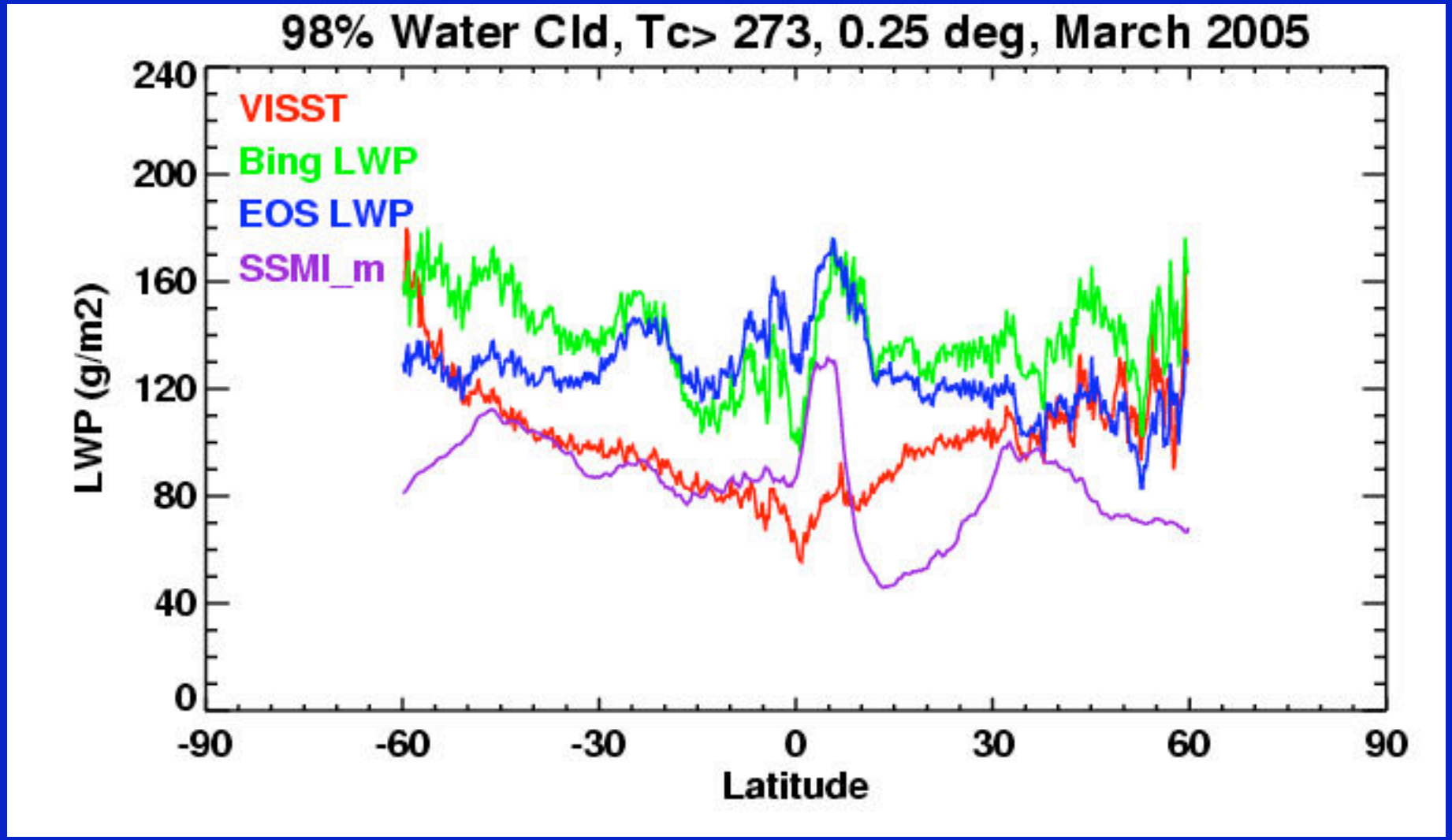


Figure 4. Seasonal variation of LWP diurnal cycle for the five regions dominated by subtropical low cloud shown in Table 1. Southern hemisphere regions are phase shifted relative to those in the north because of the seasonal reversal between hemispheres.

- **SH ocean LWP diurnal cycle much larger than NH**
- **30% bias in SH explained by diurnal cycle**

Comparison of Aqua LWP with AMSR-E

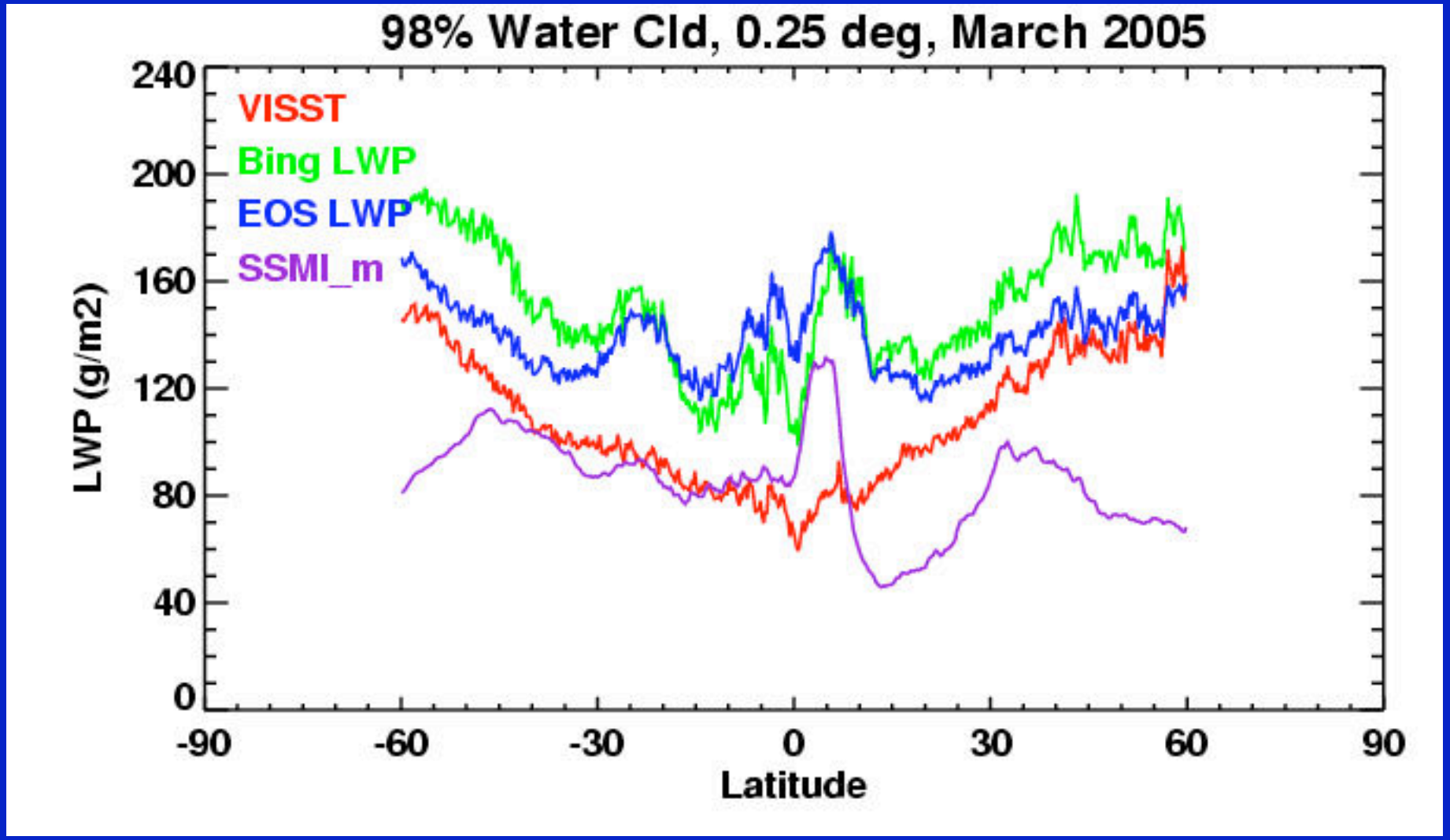
Warm overcast clouds only (SSM/I avg of all clouds)



CERES LWP 0 - 60% smaller than AMSR-E, depending on MW algorithm!

Comparison of Aqua LWP with AMSR-E

All overcast water clouds (SSM/I avg of all clouds)



CERES LWP 0 - 100% smaller than AMSR-E, depending on MW algorithm!

LWP Validation

- *Why is CERES < AMSR-E, but ≥ other measures?*

- *Continue examining LWP and sources of uncertainty*
  - *MWP calibrations*
  - *Terra calibrations*
  - *3.8-μm Solcon (10% variation)*
  - *parameterizations in retrievals*
  - *other surface datasets (ships)*

- *Adjust necessary parameters to yield most accurate results*

Proposed Edition 3 Cloud Algorithm Changes

- Account for V005 changes, use calibration information
- Improved cloud mask
- Improved thin cloud opt depth, phase, and heights
- Refined thin cirrus detection & dust/cloud discrimination
- Hi-res cloud detection and retrieval for low clouds (250-m into 1 km)
- Multilayer cloud detection & retrieval
- Multiple particle size retrievals

Cloud Mask Changes

• Added thin cirrus detection over land and ocean using MODIS 1.38, 8.55 - 11, revised 11 - 12 tests with MOA precipitable water.

• Added dust detection for dust storms from Saharan and Gobi deserts. Ocean dust tests are tuned differently between Atlantic and Pacific to better distinguish dust and low clouds

• Improved twilight cloud & snow detection for smoother transition between polar and non-polar masks

4. Other improvements:

A. Better cloud detection in low SZA

B. Cloud and snow detection in polar regions

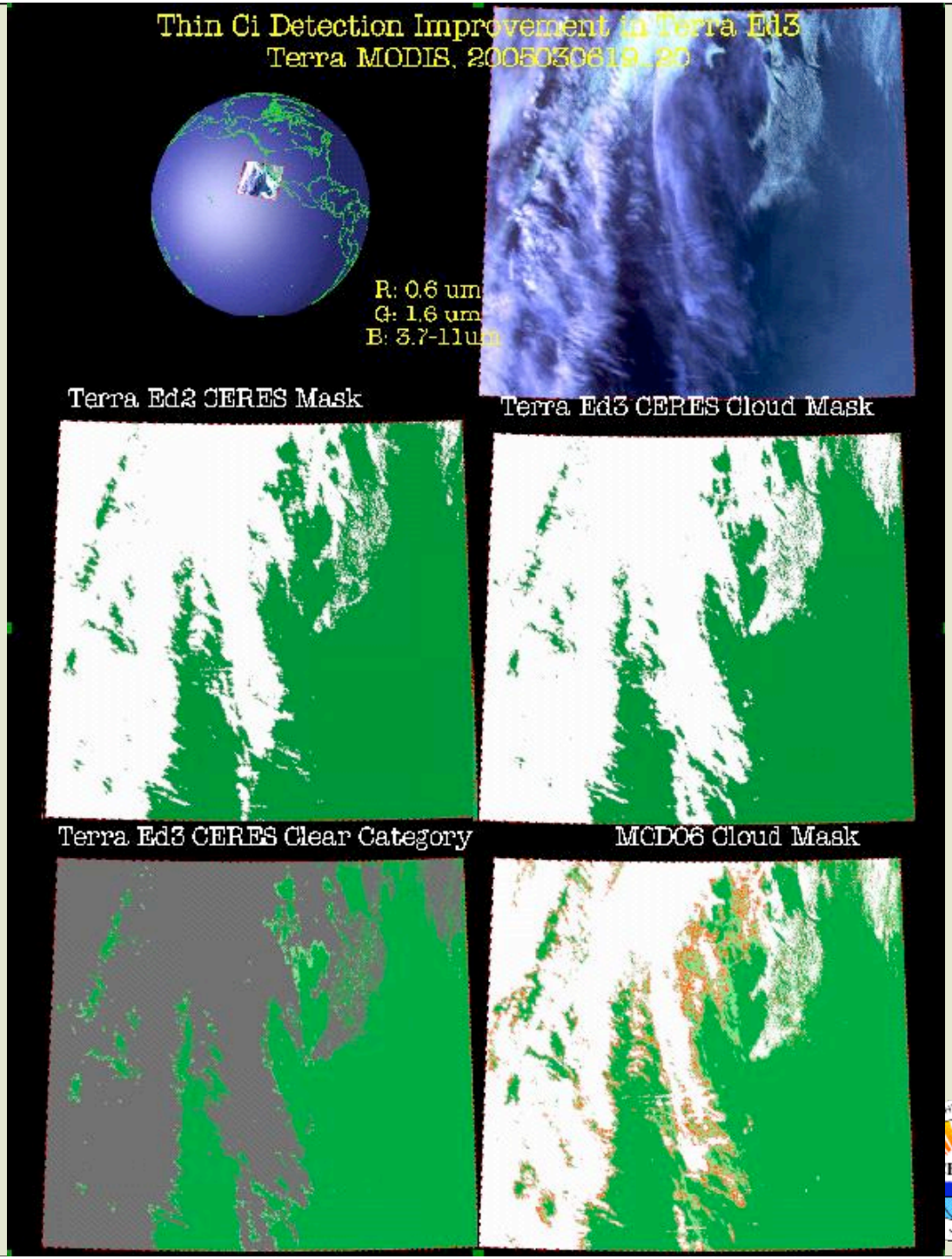
C. Snow tests over high elevations

D. Sun glint ocean and coastal regions

Thin Cirrus

Ocean example off CA coast

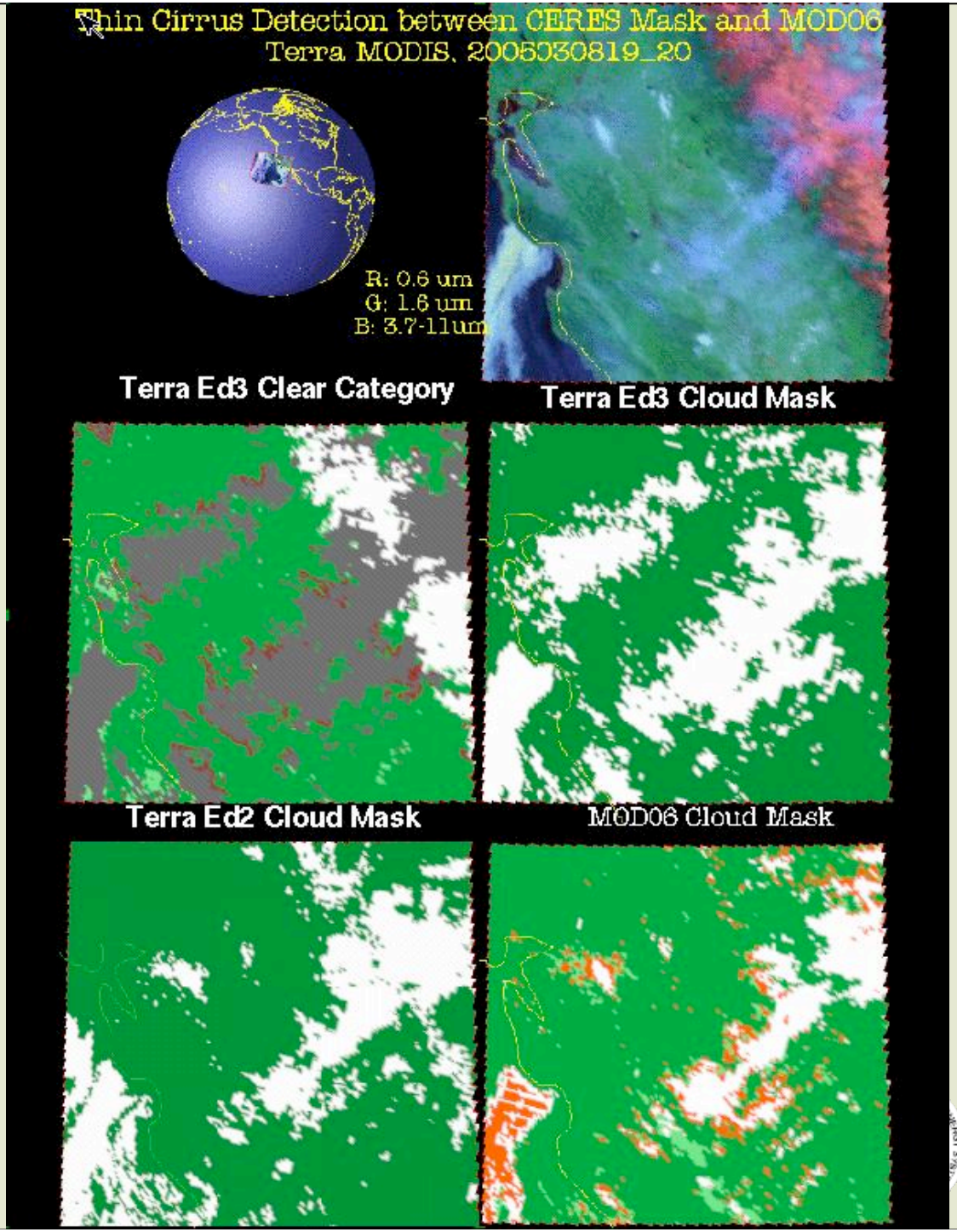
New mask picks up more cirrus than ED2 and MOD06



Thin Cirrus

Ocean example over CA

New mask picks up more cirrus than ED2 and MOD06 & more snow than ED2



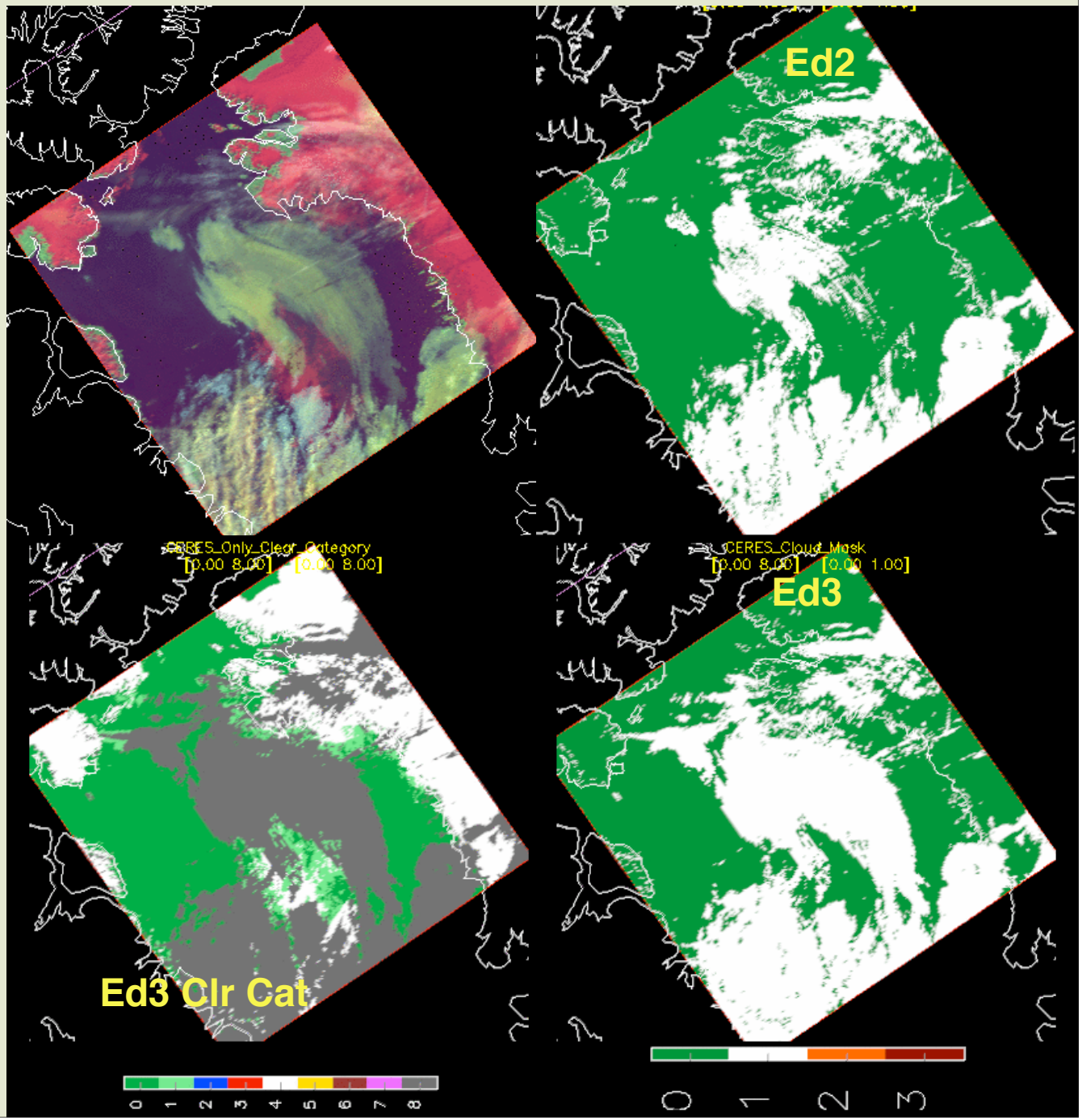
Improved mask in large SZA, twilight

Adjusted 2.1-μm threshold for sea ice and open water

More clouds detected

Example for Terra

0040 UTC
July 30, 2005



Hi-res cloud detection and retrieval for low clouds (250-m into 1 km)

- Apply VIS threshold to 250-m subpixels within 1-km pixel to estimate fractional cloud cover in pixel (16 subpixels, 4 x 4)

- Need alignment of 250-m pixels with 1-km pixels
  - assumes 1-km VIS aligned with all other 1-km channels

- Set up operational code and run examples
  - apply only over dark surfaces, no coasts
  - no ice clouds
  - no overlap

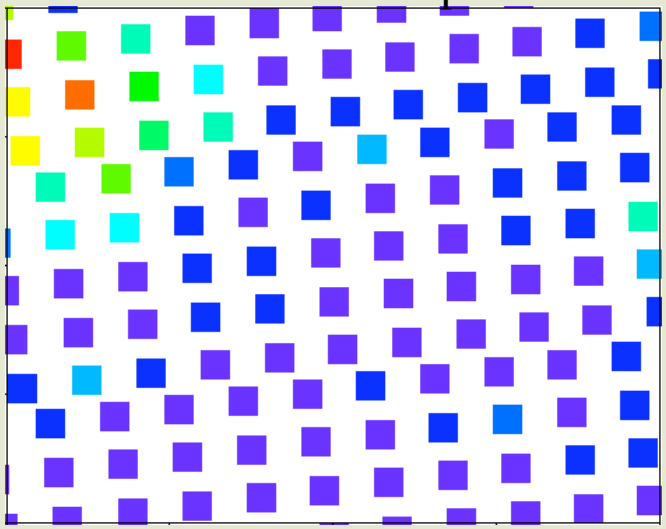
- Use examples to tune VIS thresholds

- Iterate on refinement, criteria for application

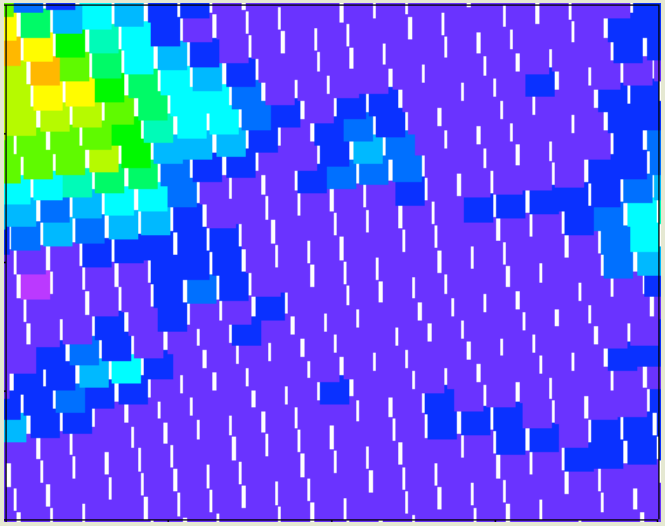
PIXEL ALIGNMENT

TERRA MODIS Reflectance from Feb 8, 2006 01:55 UTC

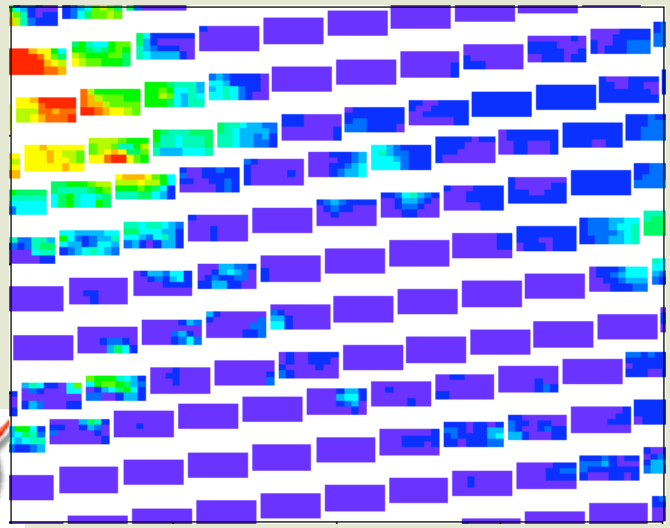
2km Sub-Sample



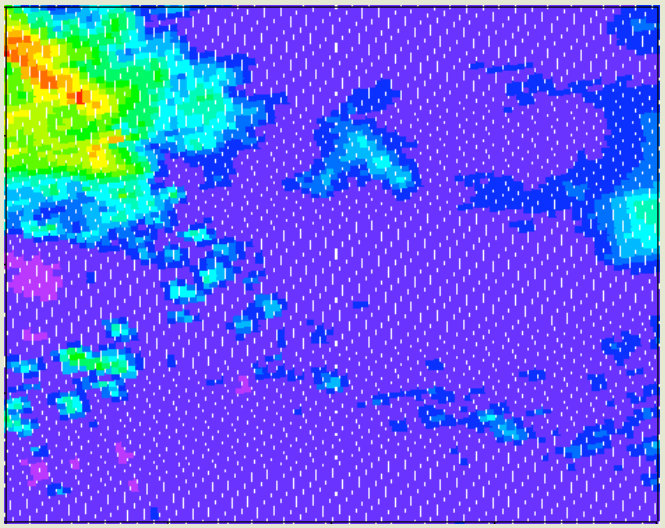
1km Full Res

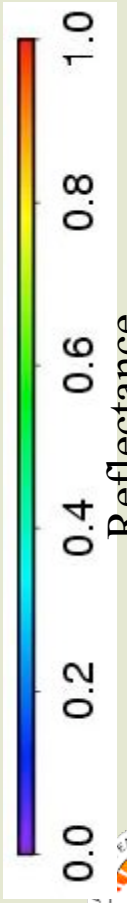


250m Sub-Sample (8x4 pixel)



250m Full Res



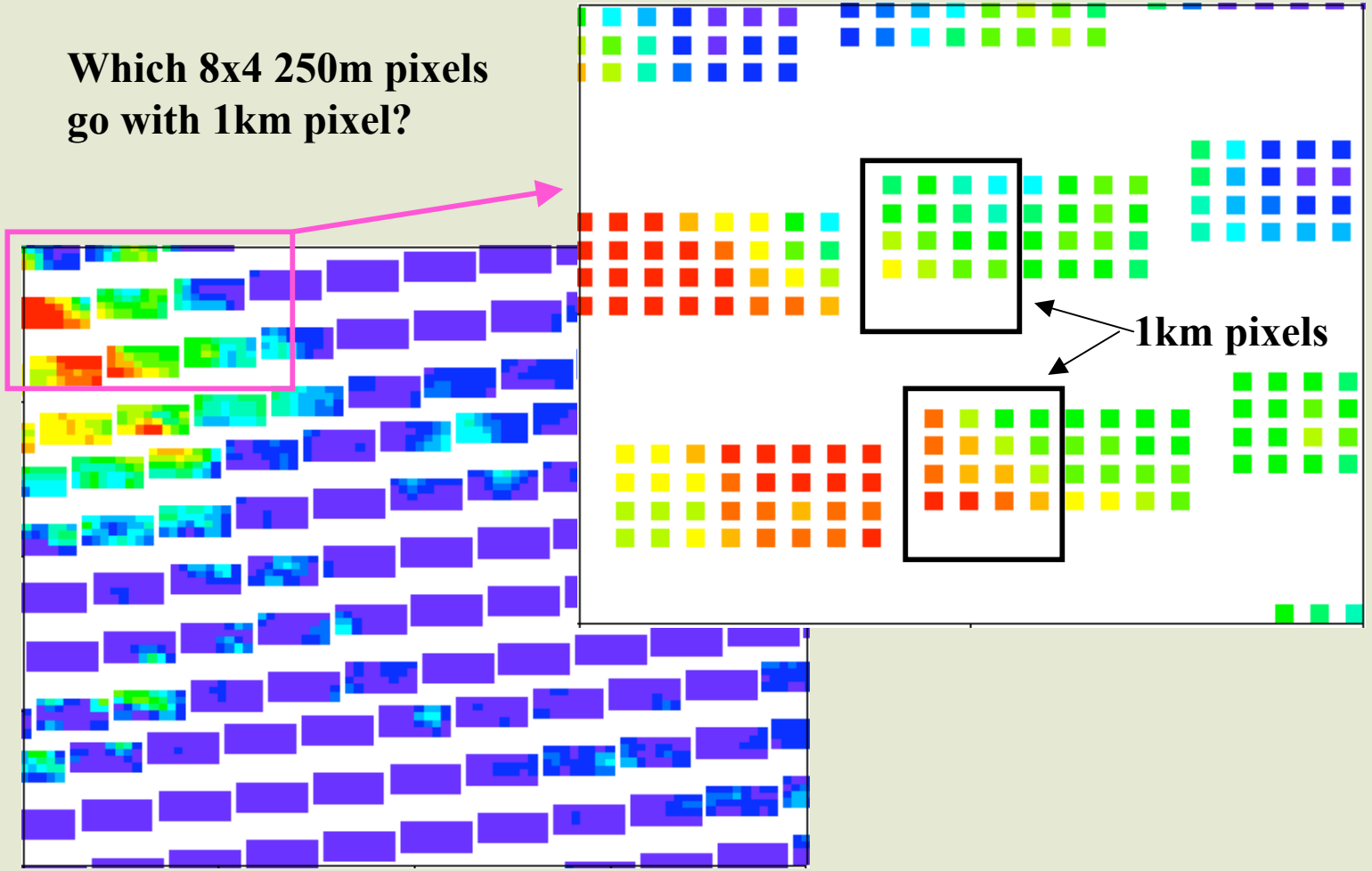


NASA

CERES

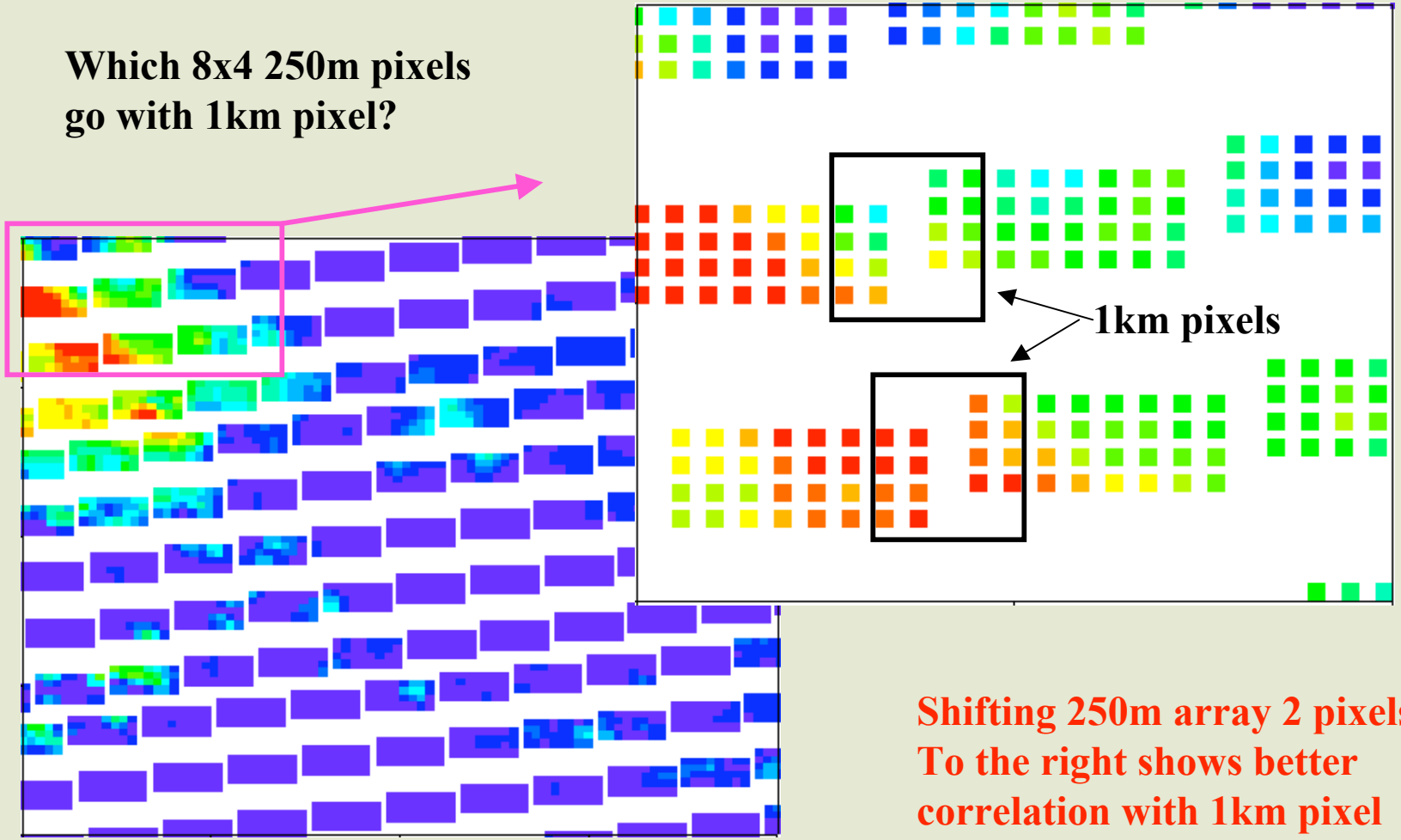
MODIS 2km and 250m Pixel Alignment

Which 8x4 250m pixels go with 1km pixel?



MODIS 2km and 250m Pixel Alignment

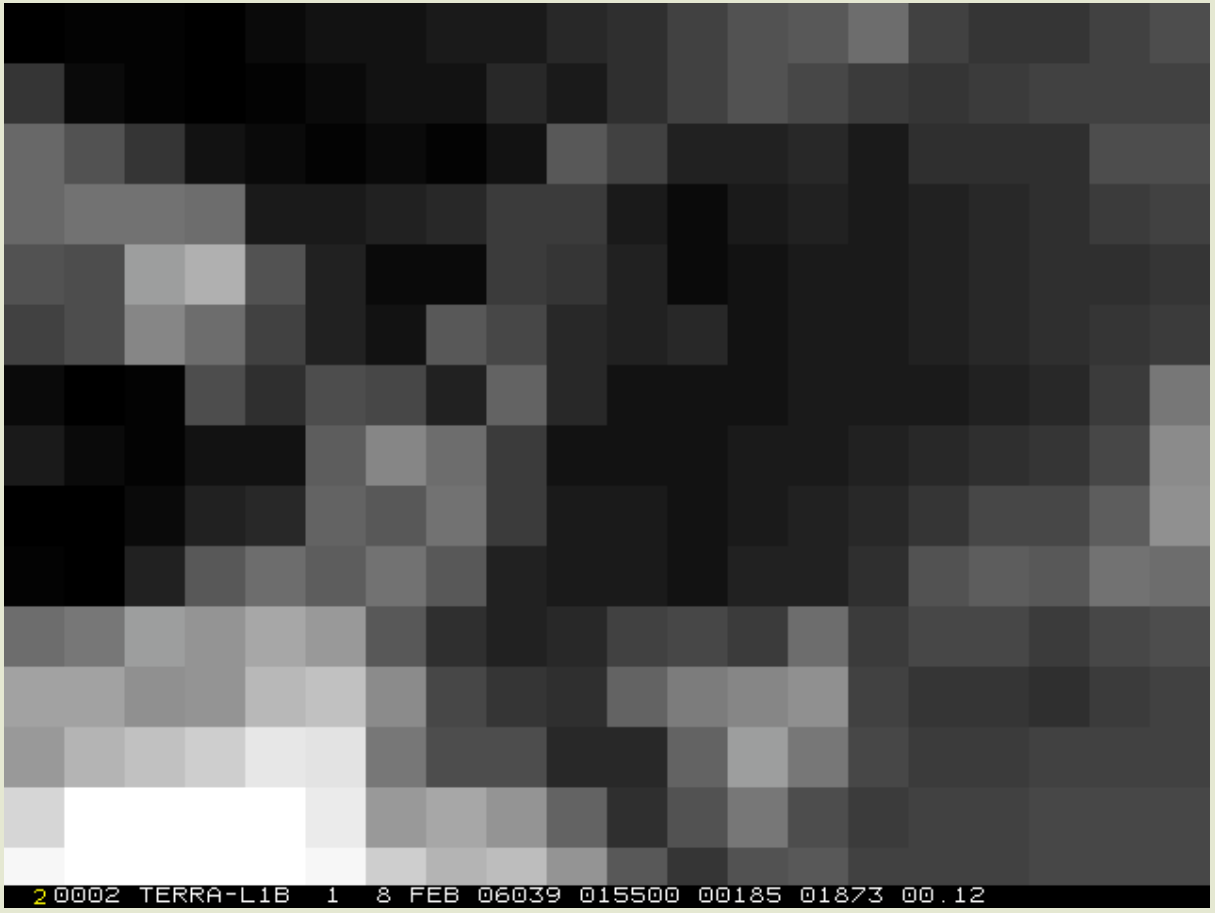
Which 8x4 250m pixels go with 1km pixel?



Shifting 250m array 2 pixels To the right shows better correlation with 1km pixel

MODIS 1km and 250m Pixel Alignment

McIDAS software shows full res MODIS data
have same alignment problem



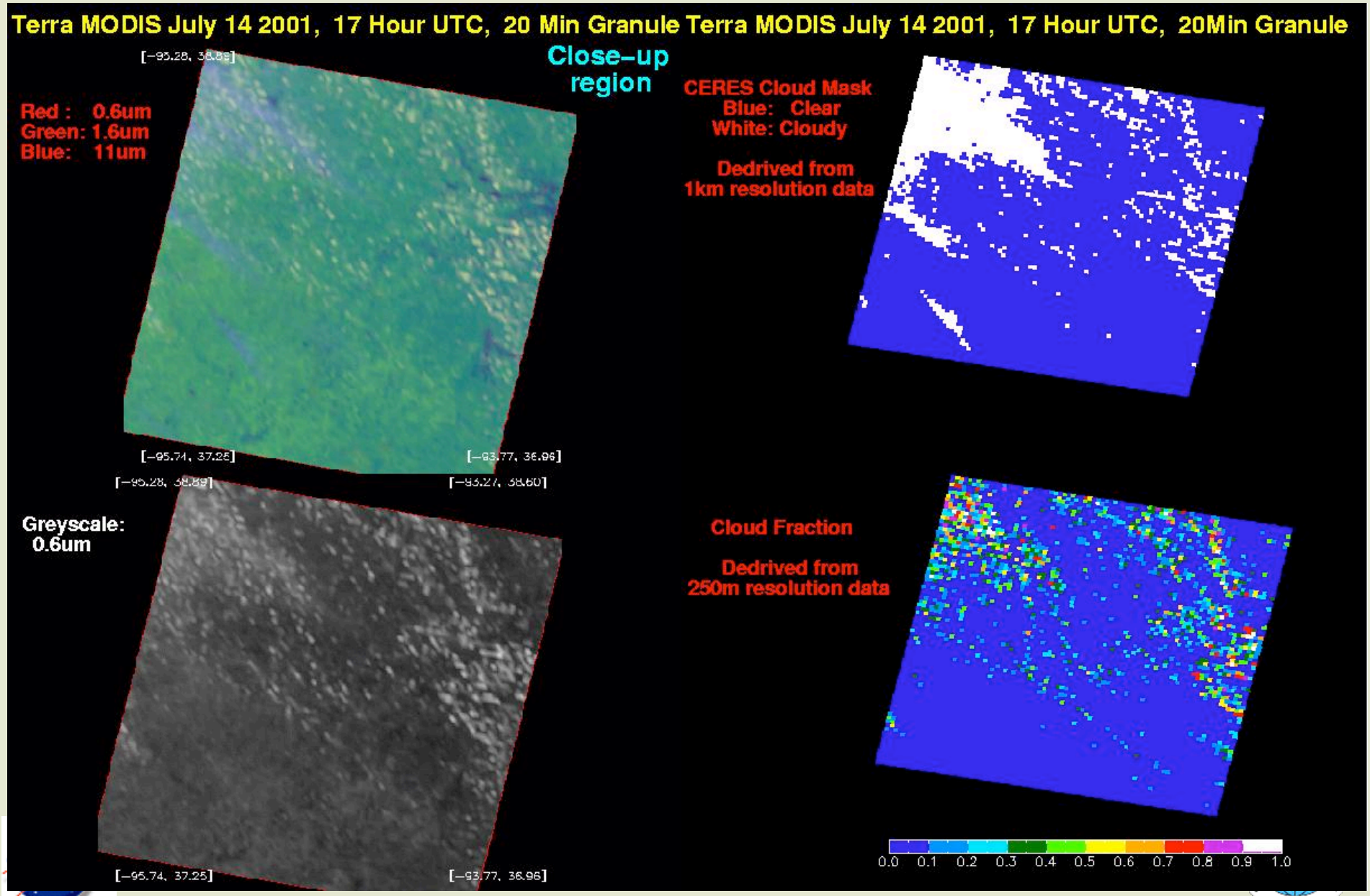
250m pixels need to be shifted 2 pixels to the right

MODIS 1km and 250m Pixel Alignment

McIDAS software shows full res MODIS data
Also have same alignment problem

250m pixels need to be shifted 2 pixels to the right

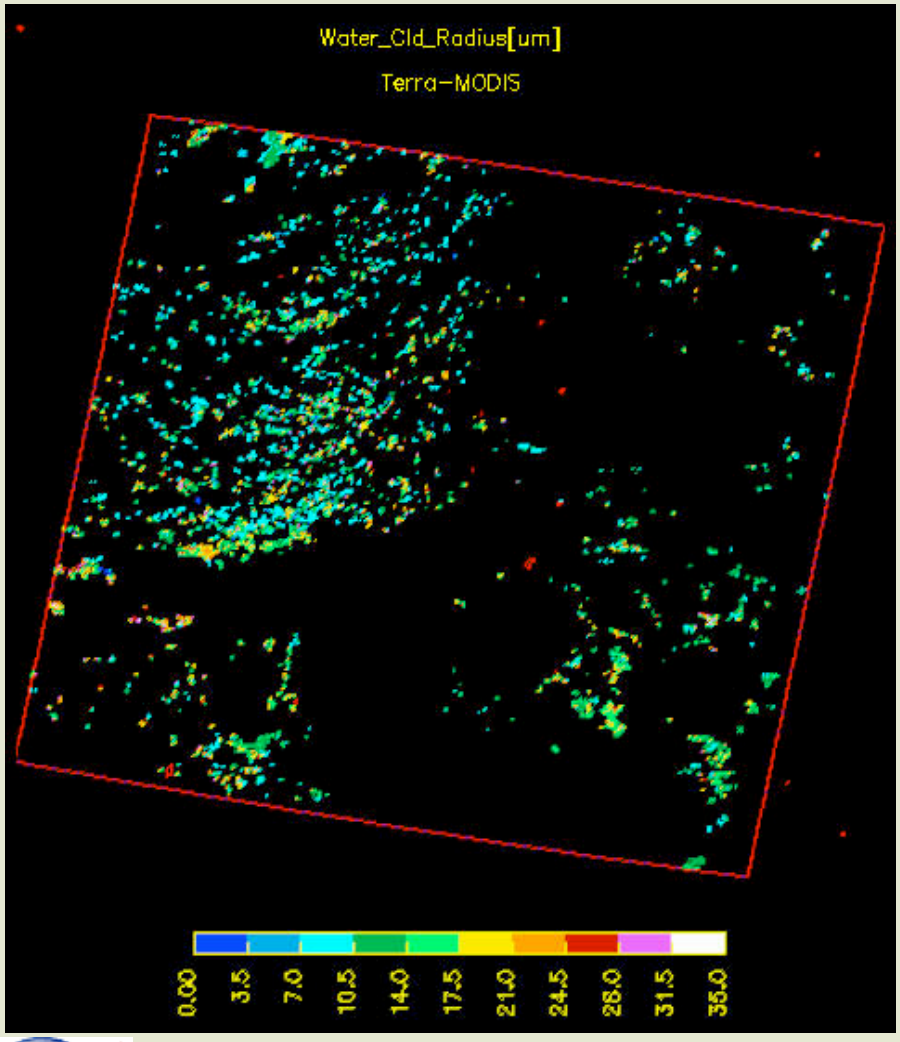
MODIS Retrievals



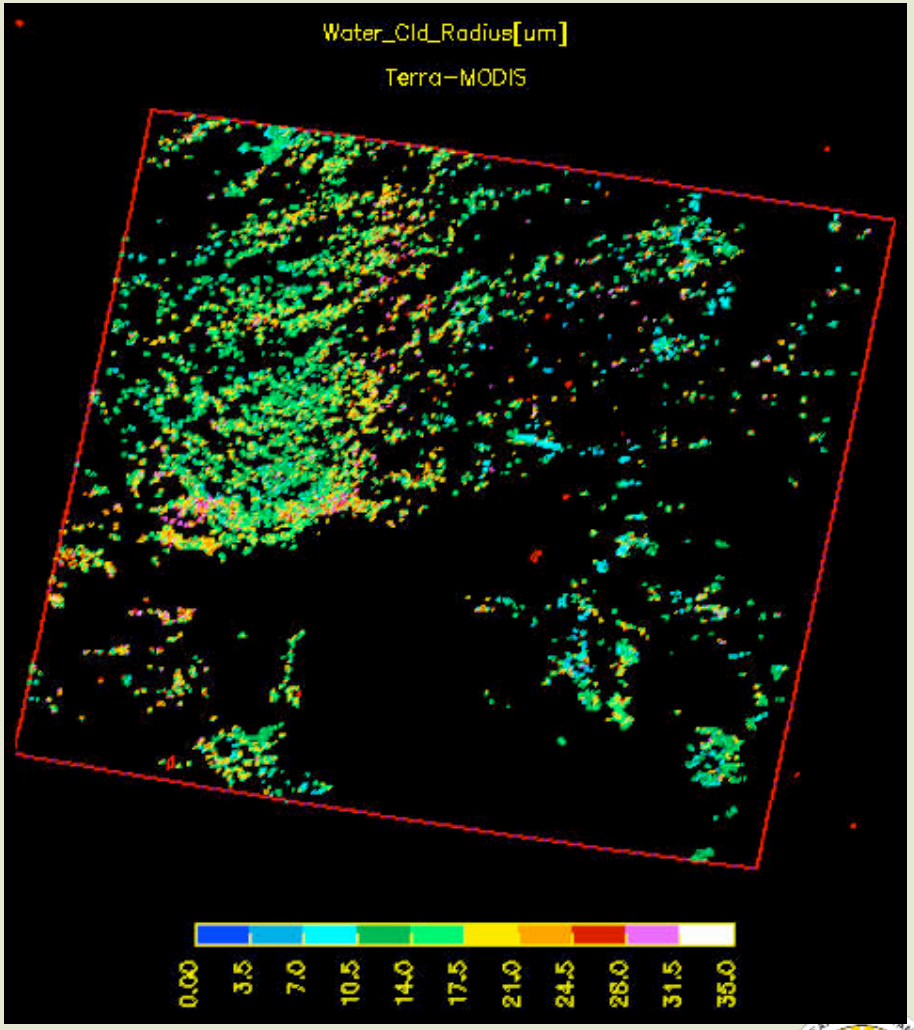
Core of Technique Is Operational

r_{eff}, Terra, July 30, 2005

250 m



1 km

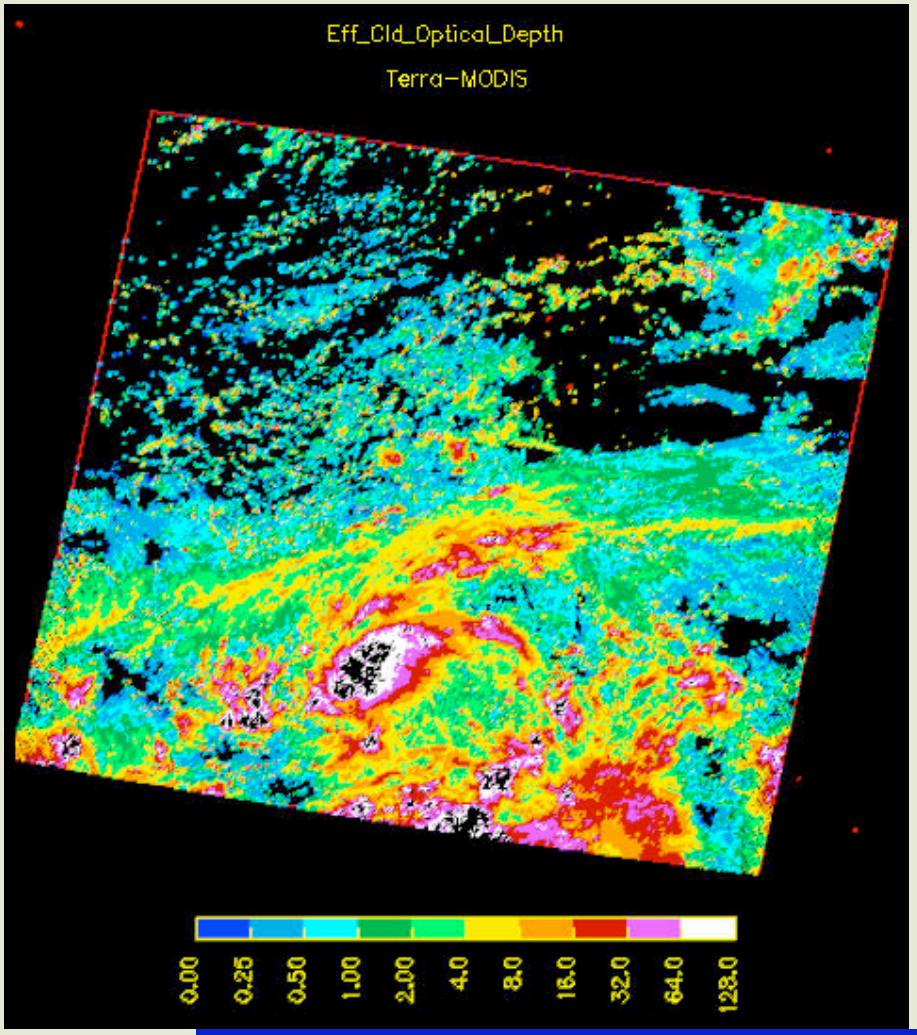


- **Initial run generally decreases reff and cloud cover!**

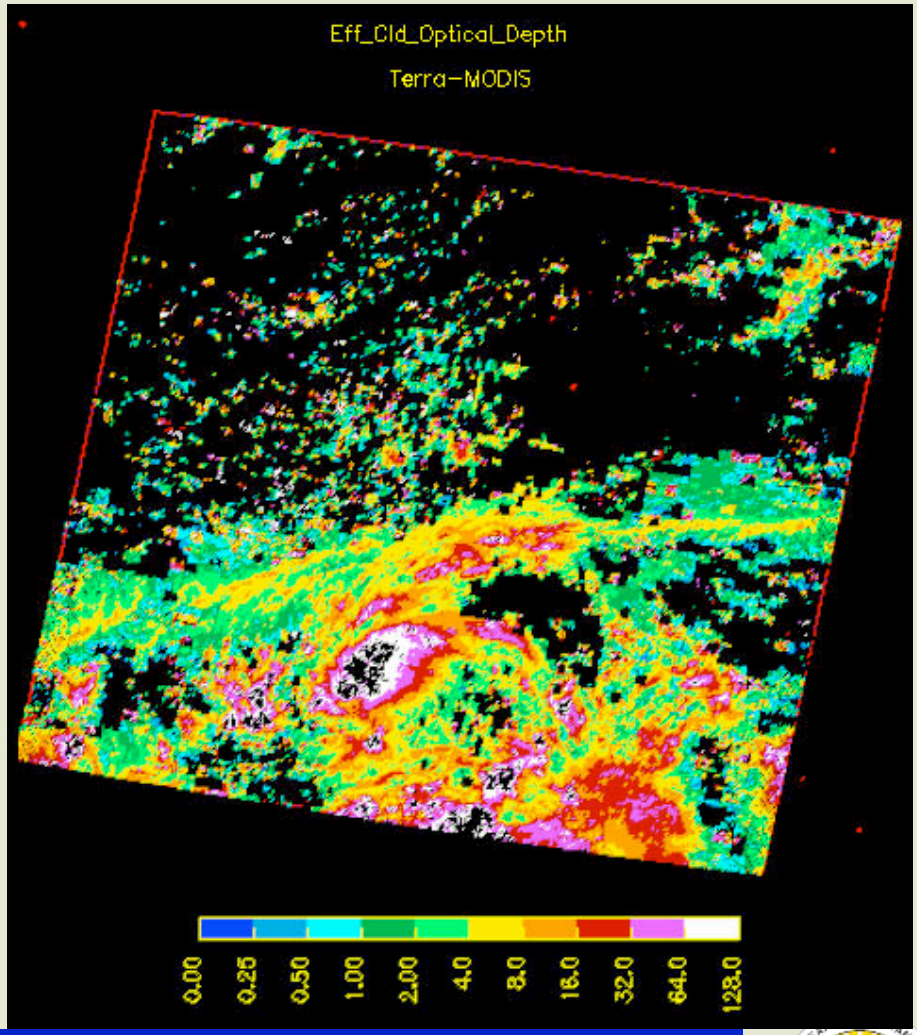
Core of Technique Is Operational

τ, Terra, July 30, 2005

250 m



1 km



- Initial run generally increases tau
  - no constraints or alignment applied yet

Future for Subpixel Cloudiness

- Adjust thresholds to maximize retrievals
  - apply constraints noted earlier
  - smooth edge effects
- Determine if true alignment not possible with sampled dataset
  - best match with 1-km VIS at +/- 4%
- Refine constraints
  - limit geography, SZA, amount of change
  - determine when to return to default value
- Finalize algorithm

Multilayer cloud detection and retrieval

- Fu-Lung Chang has joined the Langley Cloud Group via NIA

- Edition 3 will use upgrade of Chang & Li (2005) CO2-slicing/VISST overlapped cloud detection and retrieval method

- Increase in the number of parameters
  - need properties of upper and lower layer clouds
  - **Multi-layer clouds observed ~ 20% of daytime pixels, no multi-layer at night. Proposed Edition3 SSF would be ~17.7% larger than Edition2**
  - **Innovative method proposed by F. Rose to minimize impact on file sizes**

- Mechanics of method currently operational
  - refinement is ongoing
  - validation planned using surface sites

SSF Changes

Summary of changes:

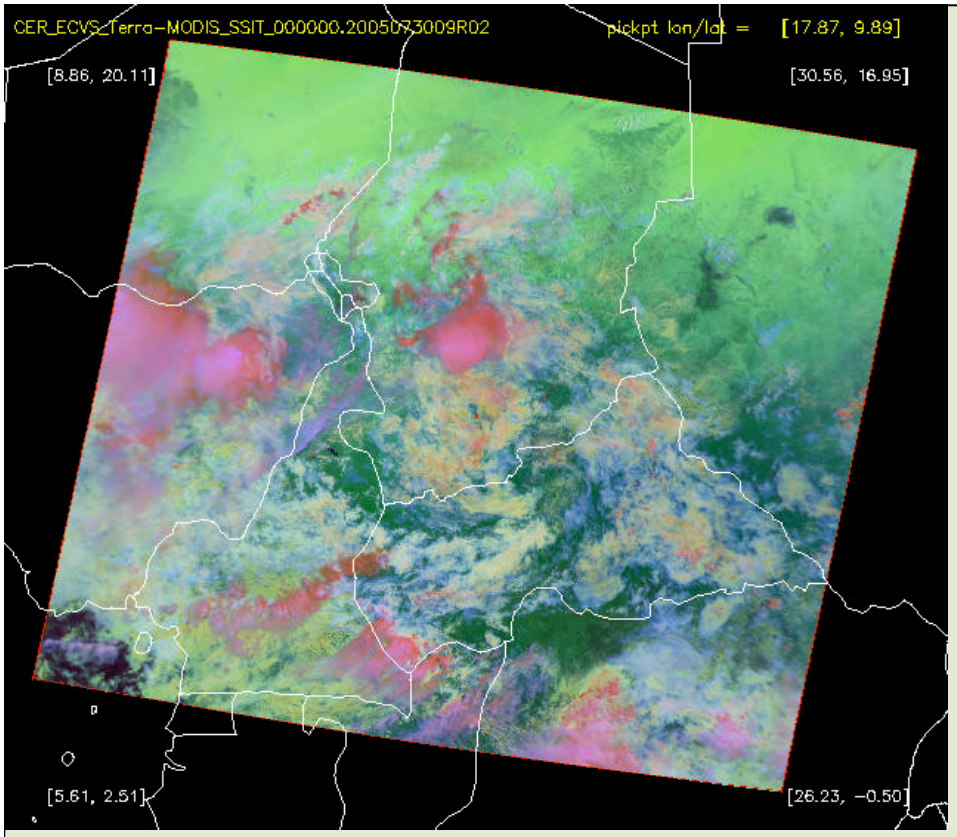
- Removed Mean and Stddev of vertical aspect ration for cloud layer (formerly SSF-111 and SSF-112) **(-4 values)**
- Removed Percentile of IR emissivity for cloud layer (formerly SSF-114) **(-26 values)**
- Add 5 new CO2 slicing parameters to the Cloud Footprint area. (See SSF-111, SSF-11a, SSF-111b, SSF-111c, and SSF-112) **(+10 values)**
- Added Multi-layer Cloud Footprint Area complete with 11 new parameters (See SSF-114a to SSF-114k) All parameters are arrays of 4: single layer 1, single layer 2, multi-layer 1, multi-layer 2. **(+44 values)**

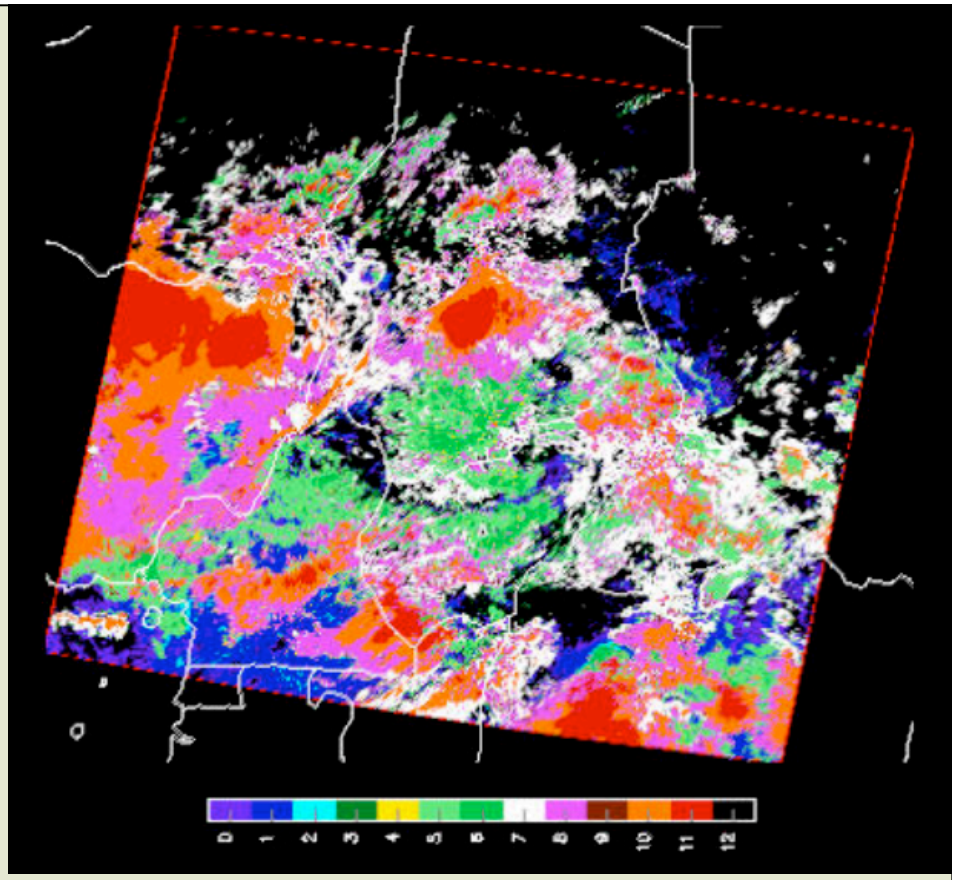
To reduce binary file size, the following was proposed:

- Do not include Multi-layer Cloud Footprint parameters in SSFB file, instead create an ancillary, multi-layer file
- In main binary file (SSFB) include only Direct Access (DA) record number to index into ancillary, multi-layer file
- If FOV contains multi-layer cloud, set DA rec # to actual record written to multi-layer file, else set it to default.
- Write multi-layer record only when at least 1 pixel in FOV contains multi-layer cloud properties. If no pixels within the FOV are identified as having multi-layer cloud properties, don't write anything.
- Include in the ancillary, multi-layer file the time of observation, the packet number, and the sample number. Time of observation uniquely identifies the FOV and packet/sample number uniquely identifies the FOV within the day. (All 3 were requested because the current day/night subsets do not maintain enough precision to uniquely identify a FOV using observation time.)

Classification of updated CO2-slicing Multi-layer Cloud Mask

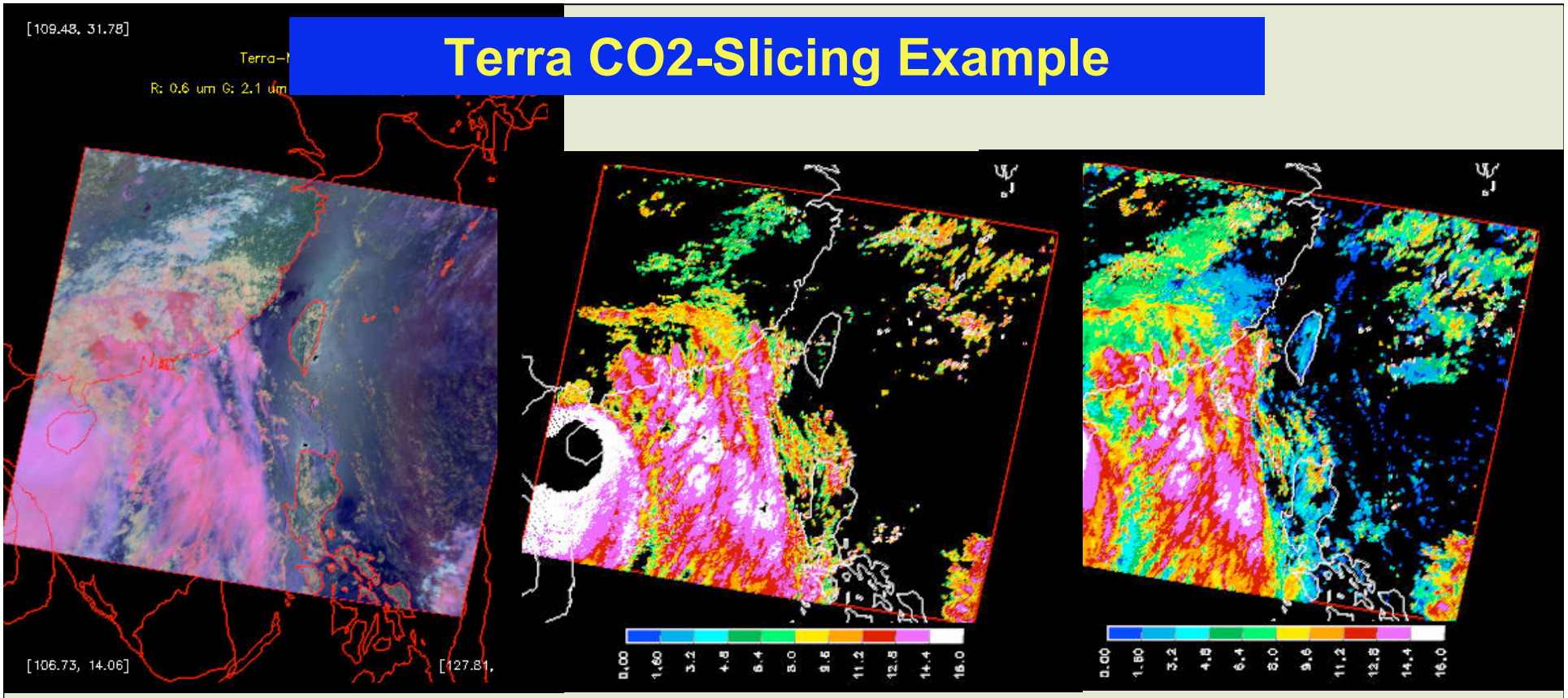
	Code	Code Description
Pc < 440 mb IR ε > 0.85	3 3 3 3 3 2 3 3 1 3 3 0	High cloud, High**3**, with adjacent mid+low High cloud, High**3**, with adjacent mid High cloud, High**3**, with adjacent low High cloud, High**3**, without adjacent mid or low
Pc < 440 mb IR ε < 0.85	3 2 3 3 2 2 3 2 1 3 2 0	High cloud, High**2**, overlap with mid+low High cloud, High**2**, overlap with mid High cloud, High**2**, overlap with low High cloud, High**2**, marginal overlap/uncertain
Pc < 440 mb IR ε < 0.85	3 1 0	High cloud, High**1**, no overlap
Pc = 440-680 mb IR ε > 0.85	2 3 1 2 3 0	Mid cloud, Mid**3**, with adjacent low Mid cloud, Mid**3**, without adjacent low
Pc = 440-680 mb IR ε < 0.85	2 2 1 2 2 0	Mid cloud, Mid**2**, overlap with low Mid cloud, Mid**2**, marginal overlap/uncertain
Pc = 440-680 mb IR ε < 0.85	2 1 0	Mid cloud, Mid**1**, no overlap
> 680 mb	1 1 0	Low cloud, Low**1**, no overlap





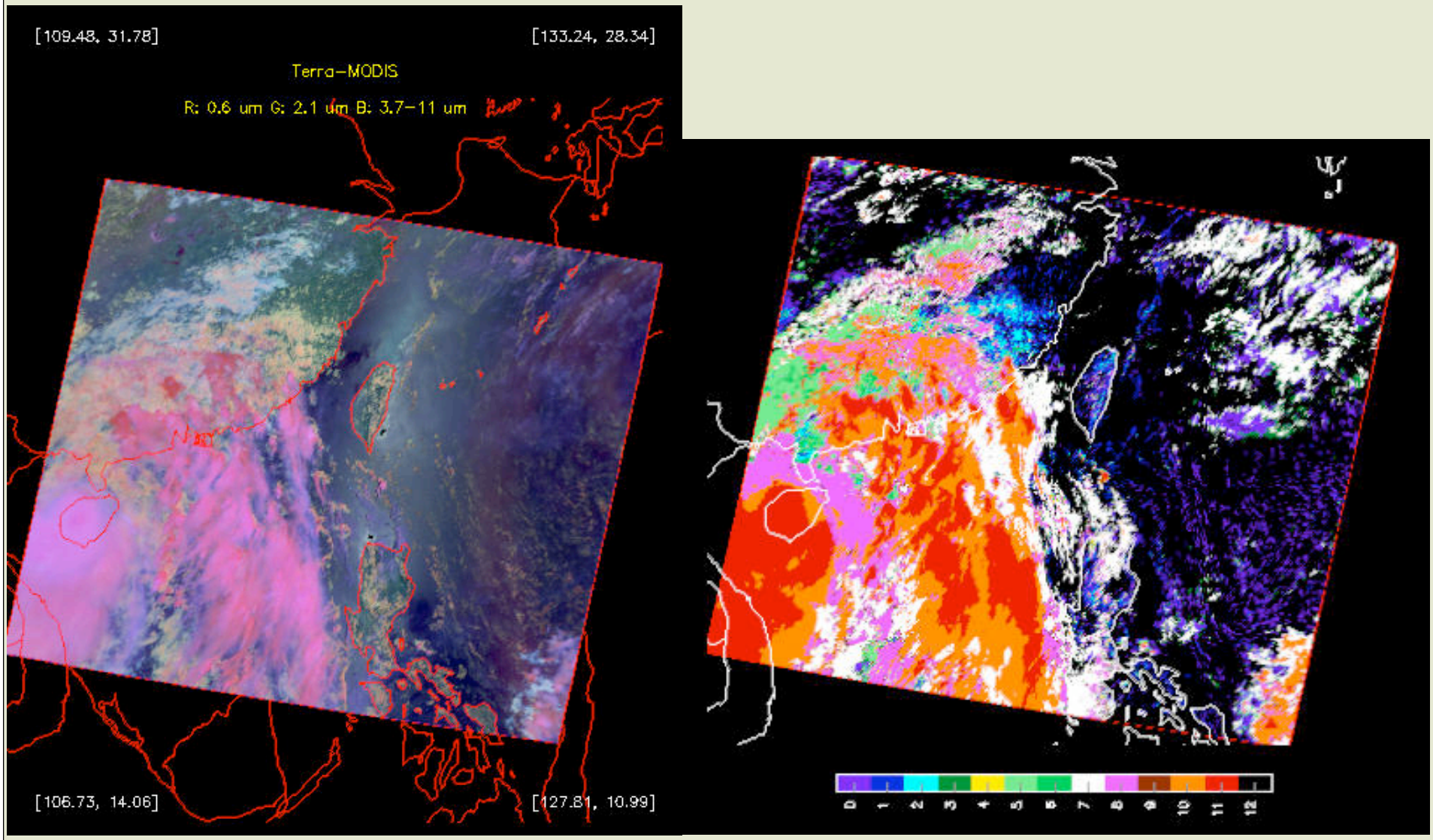
Low Cloud		Mid Cloud		High Cloud	
0 (110)	0 < τ < 3.6	3 (210)	0 < τ < 3.6	7 (310)	0 < τ < 3.6
1 (110)	3.6 < τ < 23	4 (220-221)	overlap	8 (321-323)	overlap
2 (110)	τ > 23	5 (230-231)	3.6 < τ < 23	9 (320)	marginal
		6 (230-231)	τ > 23	10 (330-333)	3.6 < τ < 23
				11 (330-333)	τ > 23

Terra CO2-Slicing Example



July 30, 2005 | CO2 Cloud Top Ht | VISST Eff Ht

Terra CO2 Overlap Example

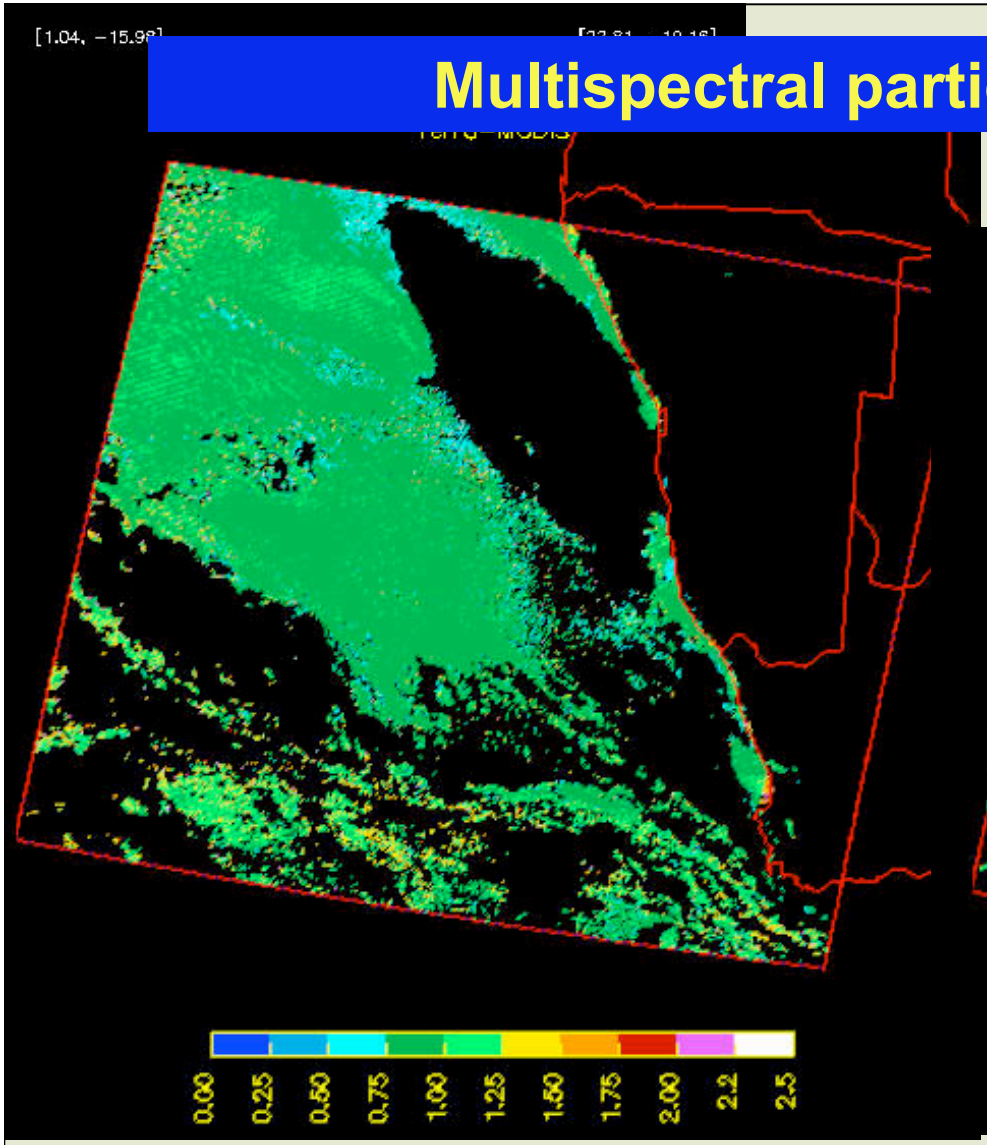


Pink & yellow are overlapped

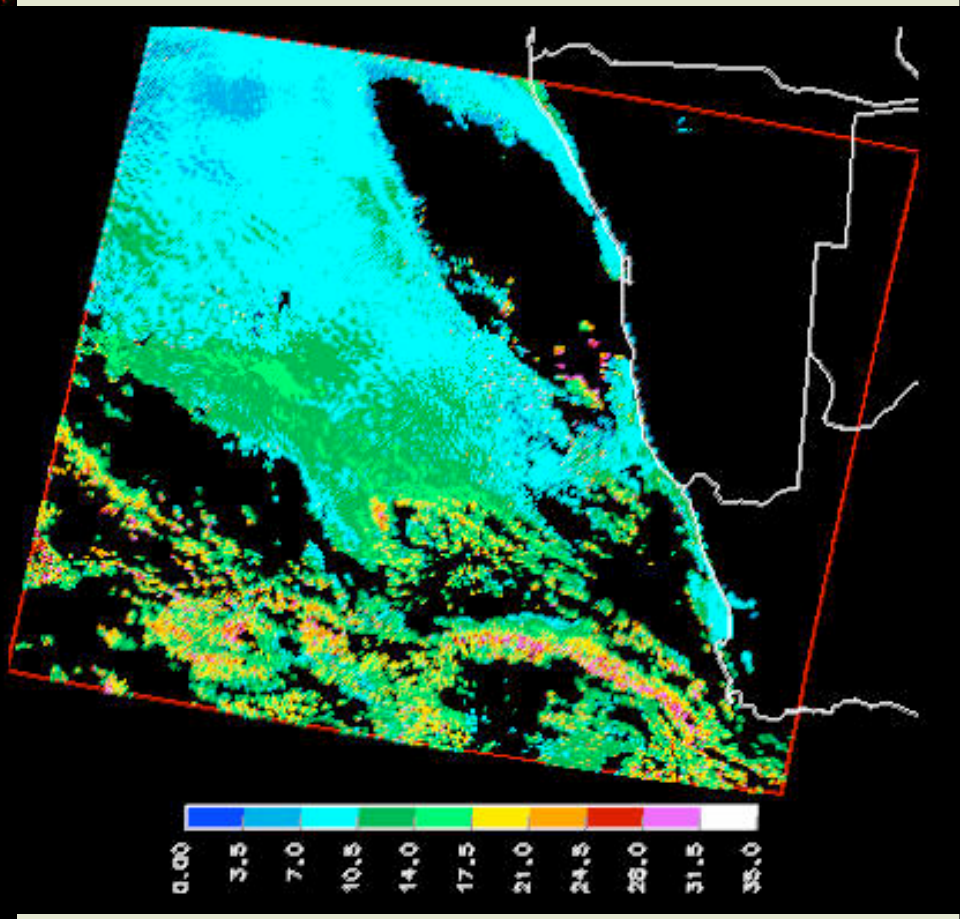
Multispectral particle size retrieval

- Two wavelengths will be used to retrieve reff or Deff in Ed3 VISST
  - not over ice/snow
  - 2.1, 3.8 μm
- Retrieval yields new size and τ, which will be added to SSF
- Results should give information about precipitation & cloud structure
- Better estimates of LWP/IWP are possible
- Possible feedback to alter phase

Multispectral particle size retrieval

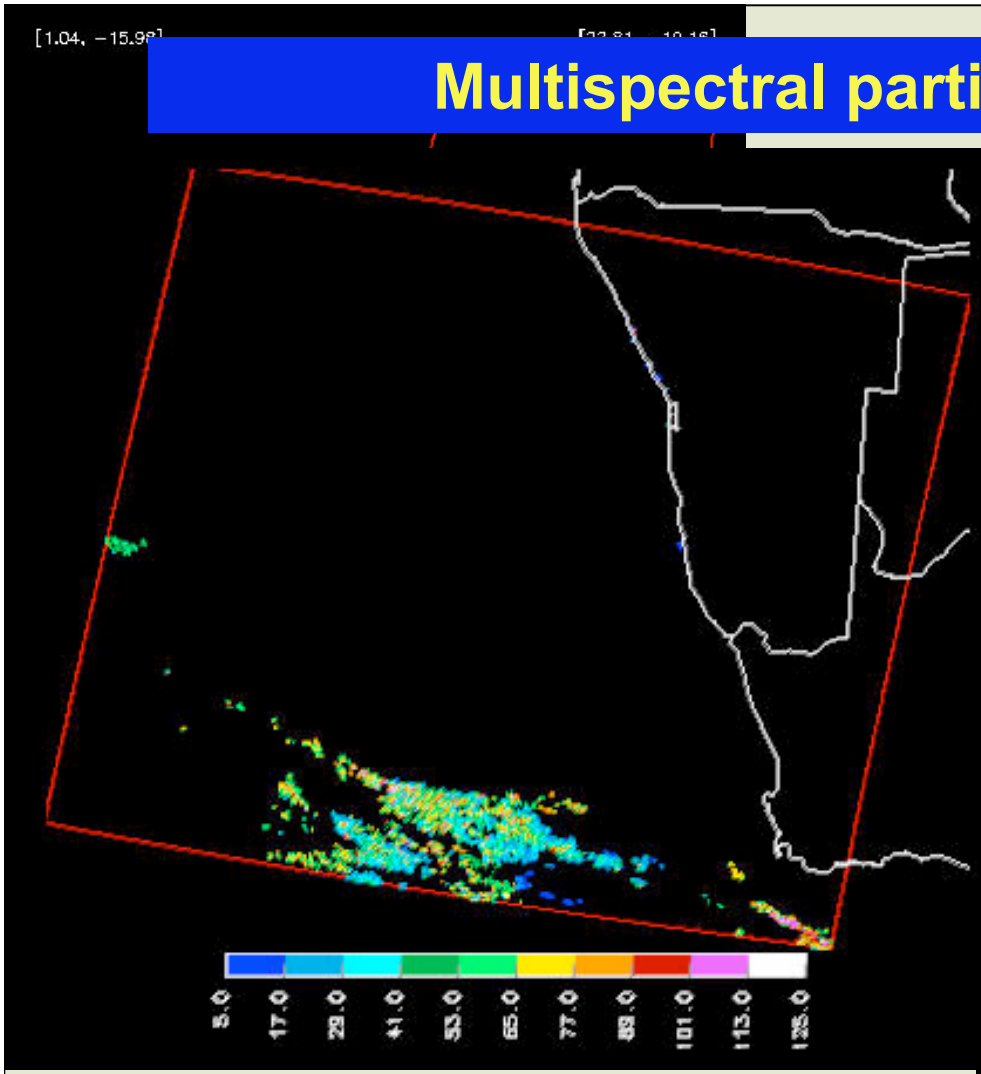


Ratio re(2.1)/re(3.7)

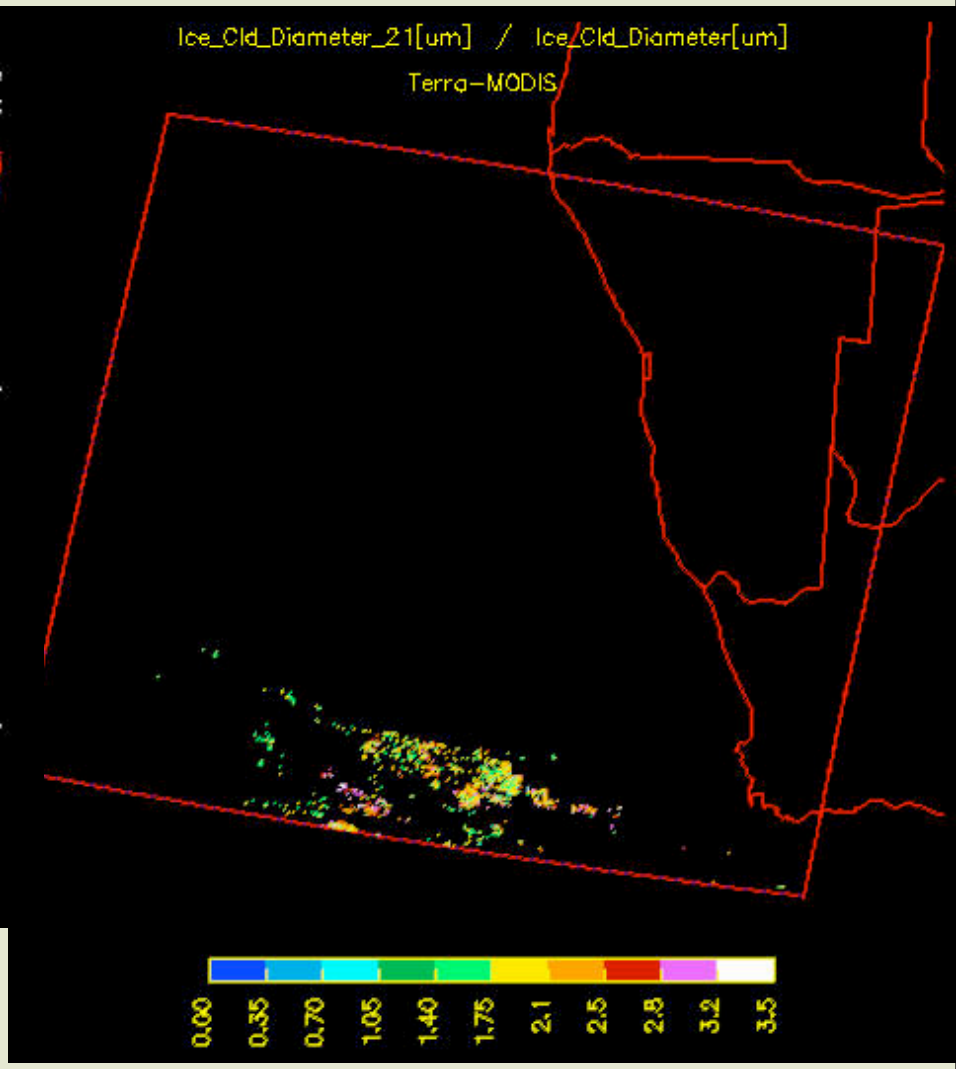


re(3.7)

Multispectral particle size retrieval

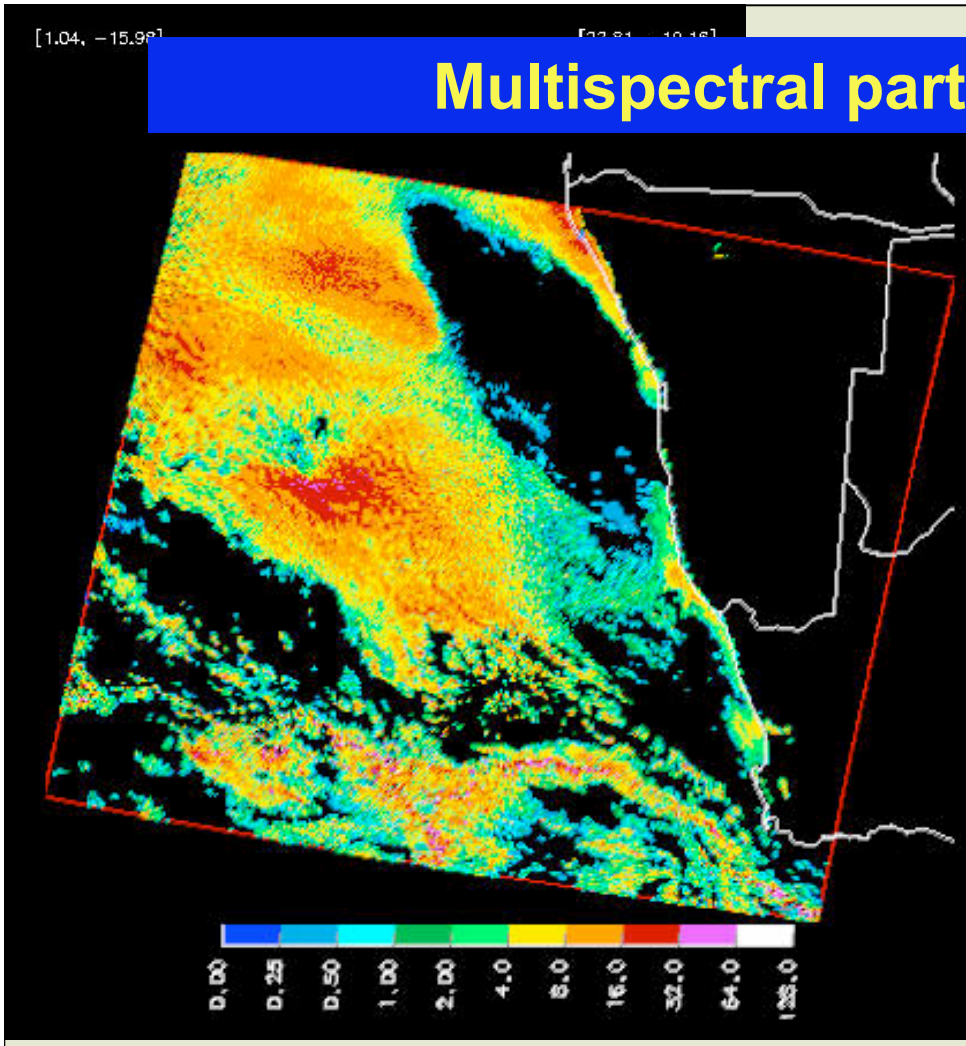


De(3.7)

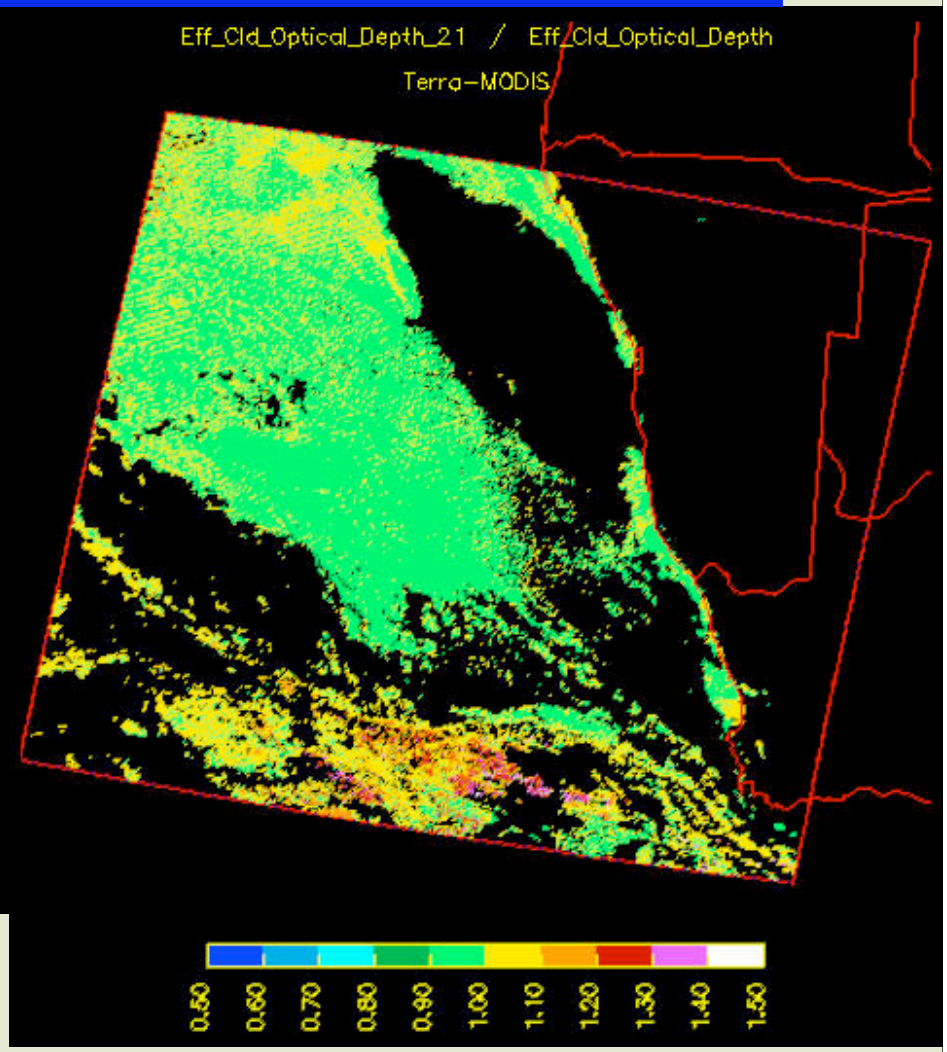


Ratio De(2.1)/De(3.7)

Multispectral particle size retrieval



τ(3.7)



Ratio τ(2.1)/τ(3.7)

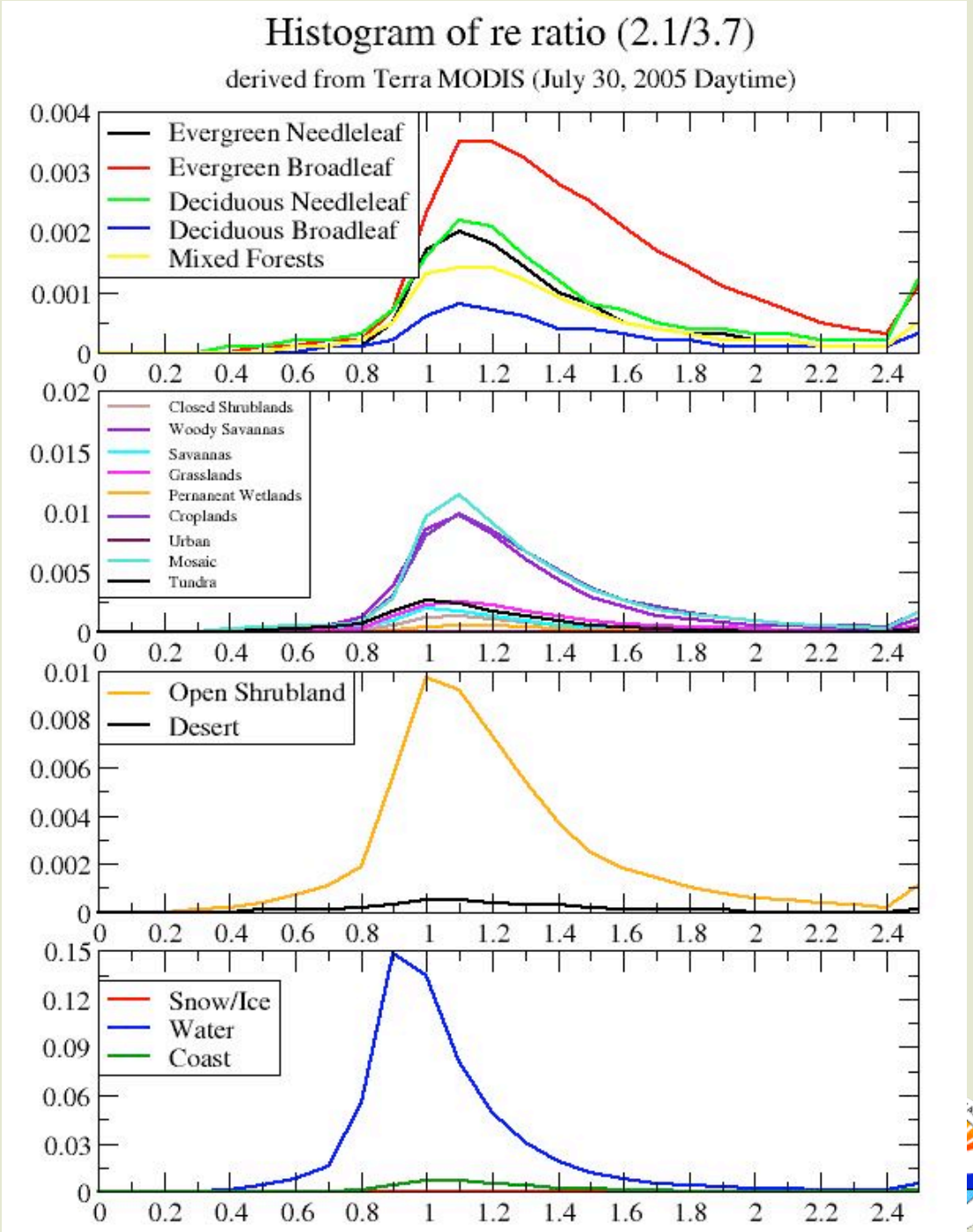
Summary of re Ratios

July 30, 2005

Ratio > 1 for most IGBP types

Ocean is exception, 50-50

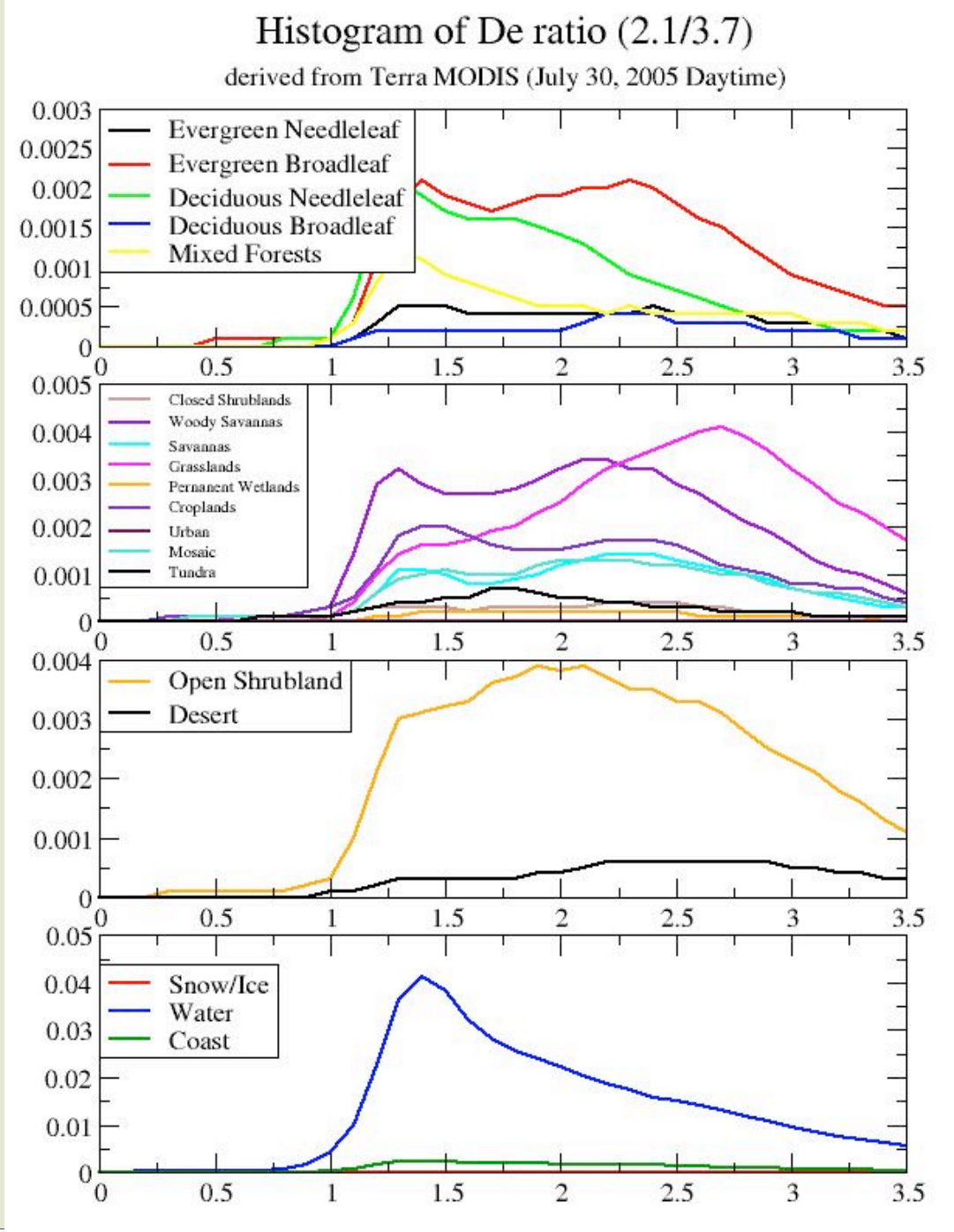
More drizzling clouds?



Summary of De Ratios

July 30, 2005

Ratio > 1 for all IGBP types

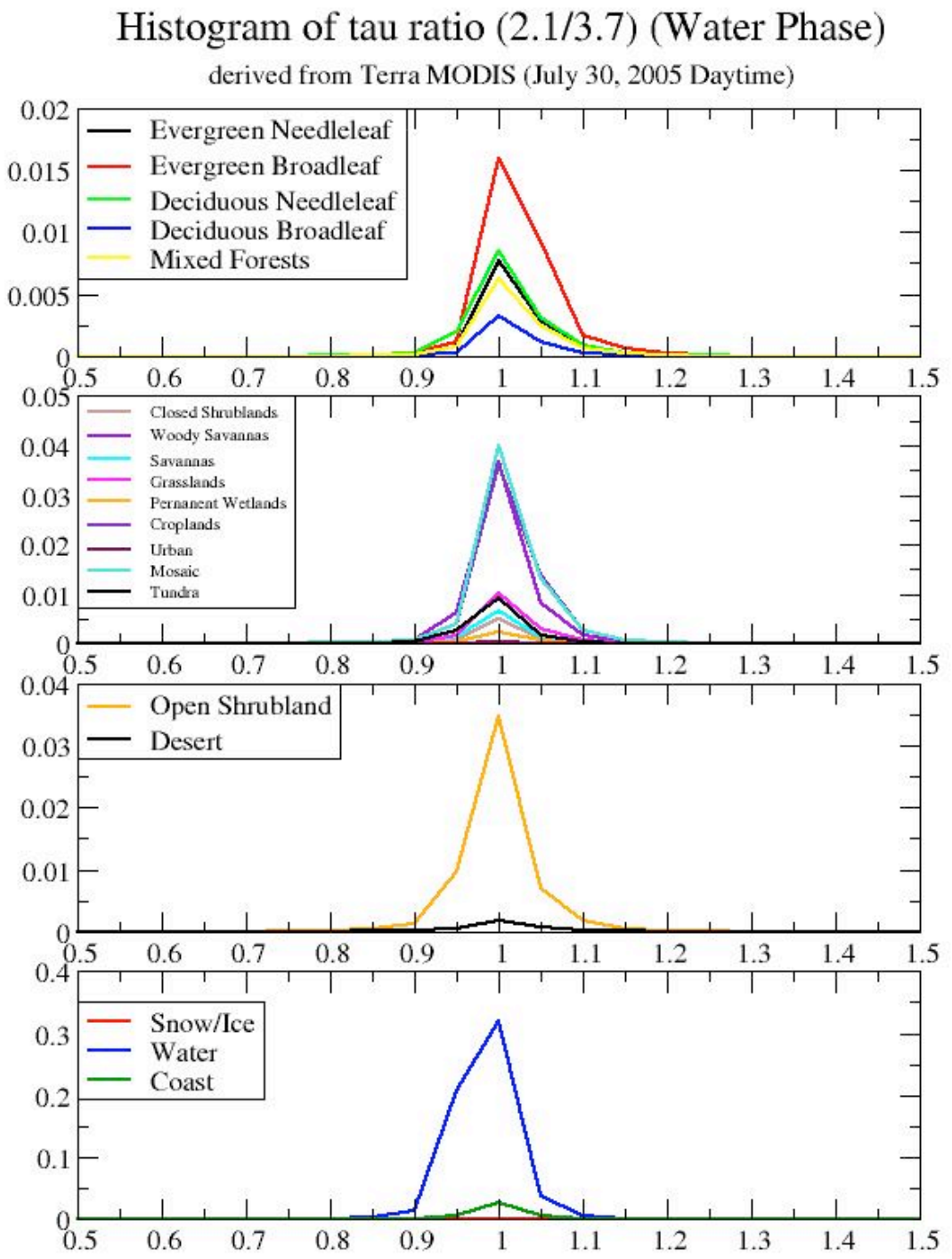


Summary of τ Ratios for water clouds

July 30, 2005

Ratio between 0.9 and 1.1 for all IGBP types

Ice ratios skewed more to > 1.0



Multispectral particle size retrieval

- Code is operational
  - refinements needed before Beta runs
  - 2.1, 3.8 μm
- Retrieval yields new size and τ, which will be added to SSF
- Results should give information about precipitation & cloud structure
- Better estimates of LWP/IWP are possible
- Possible feedback to alter phase

OTHER ISSUES TO BE HANDLED IN ED3

- Smoother polar transition
- mixed phase clouds in Arctic (flag only)
- General mask/retrieval & calibration upgrades
  - fix lapse rate approach in midlevel inversion cases
- 1.6 vs 2.1 μm: 2.1 only for Terra SINT?
- Improved clear-sky

  Use MODIS clear-sky or our maps
  - code changes in VIS parameterization
- Streamline code=> faster
- Team's suggestions
  - Charlock has plenty!

8 Papers published/accepted related to CERES Clouds since last STM

• Chepfer, H., V. Noel, P. Minnis, D. Baumgardner, L. Nguyen, G. Raga, M. J. McGill, and P. Yang, 2005: Particle habit in tropical ice clouds during CRYSTAL-FACE: Comparison of two remote sensing techniques with in situ observations. *J. Geophys. Res.*, **110**, D16204, 10.1029/2004JD005455.

• Zhao, T. X.-P., I. Laslo, P. Minnis, and L. Remer, 2005: Comparison and analysis of two aerosol retrievals over the ocean in Terra/CERES-MODIS Single Scanner Footprint (SSF) data: Part I - Global evaluation. *J. Geophys. Res.*, **110**, D21, D21209, 10.1029/2005JD005851.

•Zhao, T. X.-P., I. Laslo, P. Minnis, and L. Remer, 2005: Comparison and analysis of two aerosol retrievals over the ocean in Terra/CERES-MODIS Single Scanner Footprint (SSF) data: Part II - Regional evaluation. *J. Geophys. Res.*, **110**, D21, D21209, doi:10.1029/2005JD005852.

• Sharon, T. M., B. A. Albrecht, H. H. Jonsson, P. Minnis, M. M. Khaiyer, T. M. Van Reken, J. Seinfeld, and R. Flagan, 2006: Aerosol and cloud microphysical characteristics of rifts and gradients in maritime stratocumulus clouds. *J. Atmos. Sci.*, **63**, 983-997.

• Huang, J., P. Minnis, B. Lin, T. Wang, Y. Yi, Y. Hu, S. Sun-Mack, and K. Ayers, 2006: The effect of Asian dust aerosols on cloud properties and radiative forcing from MODIS and CERES. *Geophys. Res. Lett.*, **33**, 10.1029/2005GL024724.

• Ignatov, A., P. Minnis, W. Miller, B. Wielicki, and L. Remer, 2006: Consistency of global MODIS aerosol optical depths over ocean on Terra and Aqua CERES SSF datasets. Accepted, J. *Geophys. Res*.

• Chiriaco, M., et al., 2006: Comparison of CALIPSO-like, LaRC, and MODIS retrievals of ice cloud properties over SIRTA in France and Florida during CRYSTAL-FACE. Accepted, *J. Appl. Meteorol. Climatol.*

• Lin, B., B. A. Wielicki, P. Minnis, L. Chambers, K. Xu, Y. Hu, and A. Fan, 2006: The effect of environmental conditions on tropical deep convective systems observed from the TRMM satellite. Accepted, *J. Climate*.

7 Papers submitted/ready related to CERES Clouds since last STM

• Verlinde, H., et al., 2006: The Mixed-Phase Arctic Cloud Experiment (M-PACE). Submitted to *Bull. Am. Meteorol. Soc.*

• Chepfer, H., P. Dubuisson, M. Chiriaco, P. Minnis, S. Sun-Mack, and E. D. Riviere, 2006: Negative brightness temperature differences (11-12 μm) in cold thick ice clouds: A signature of nitric acid. Submitted to *Remote Sens. Environ.*

• Chepfer, H., P. Minnis, P. Dubuisson, M. Chiriaco, S. Sun-Mack, and E. D. Riviere, 2006: Nitric acid particles in cold thick ice clouds observed at global scale: Link with lightning, temperature, and upper tropospheric water vapor. Submitted to *J. Geophys. Res.*

• Chepfer, H., P. Dubuisson, P. Minnis, A. Hauchecorne, M. Chiriaco, and S. Sun-Mack, 2006: Observations of nitric acid particles in cloudy conditions in polar regions by passive remote sensing. Submitted to *J. Appl. Meteorol. Climatol.*

• Huang, J., B. Lin, P. Minnis, T. Wang, X. Wang, Y. Hu, Y. Yi, and J. K. Ayers, 2006: Satellite-based assessment of possible dust aerosols semi-direct effect on cloud water path over east Asia. *Geophys. Res. Lett.*

• Kato, S., N. G. Loeb, P. Minnis, J. A. Francis, T. P. Charlock, D. A. Rutan, and E. E. Clothiaux, 2006: Seasonal and interannual variations of top-of-atmosphere irradiance and cloud cover over the Arctic derived from the CERES data set. Submitted, *Geophys. Res. Lett.*

• Minnis, P., D. R. Doelling, L. Nguyen, and W. F. Miller, 2006: Intercalibration of the visible channels on the TRMM VIRS and MODIS on Terra and Aqua. *J. Atmos. Oceanic Technol.*, in preparation.